PERDIGAO NCAR Radiosonde Data Quality Report

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The radiosonde data for this project were quality controlled and are maintained by the Earth Observing Laboratory at the National Center for Atmospheric Research (NCAR). NCAR is sponsored by the National Science Foundation (NSF). In the event that information from this document is used for publication or presentation purposes, please provide appropriate acknowledgement to NSF and NCAR/EOL and make reference to Young K., W. Brown and H. Vömel (2015): PERDIGAO 2017 NCAR Radiosonde Data Quality Report.

In the event that these datasets are used for research resulting in a publication, please include the following citations in your paper:

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PERDIGAO 2017 Quality Controlled Radiosonde Dataset

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Document Version Control

Version	Date	Author	Change Description
1.0	01/28/2017	*K. Young*	Initial Document Release
2.0	02/08/2017	*K. Young*	Noted irregular profiles in the report, D20170507_050533 and D20170512_051405. Turned off monotonic pressure check in ASPEN for all but one profile. Set prelaunch sonde measurements from the surface to equal time=0. Made minor edits to report.

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I. Dataset Overview

The PERDIGAO field campaign was a large-scale, multi-national, multi-agency, research project conducted in Portugal with operations centered in Alvaiade (Figures 1 and 2). Participating institutions included the University of Porto, Denmark Technical University, the Portuguese Institute for Sea and Atmosphere (IPMA), the National Science Foundation (NSF), University of Notre Dame, University of Colorado, Boulder, University of Oklahoma, Cornell University, University of California at Berkeley, and the U.S. Army Research Lab. The primary goal of the field campaign was to collect wind measurements at an unprecedented spatial scale and to create numerical models that better represent turbulence and wind flow in areas of complex terrain. The National Center for Atmospheric Research's Earth Observing Laboratory (NCAR/EOL) deployed one fixed Integrated Sounding System (ISS) located at 7 44.19'W and 39 42.82'N, approximately 330 meters North of Vale Cobrão, also referred to by researchers as the 'Upper Orange Grove Sounding Site'.

Two hundred balloon-borne radiosondes were launched between May 01 and June 15, 2017. The intent of collecting data from the radiosondes was to provide in-situ validation for the remote sensing data collected in the boundary layer. This document contains a link to information on the sounding file format, data parameters included in each of the files, and it includes information regarding data quality and the quality control routines applied to the sounding data.

Figure 1 – Map of Portugal shows the sounding site location indicated by the red marker.

Figure 2 – Satellite image of the Valley instrumented with ISFS Flux towers and other instrumentation, located between Perdigao and Alvaiade.

For more information on the PERDIGAO project please visit following sites:
https://www.eol.ucar.edu/field_projects/perdig%C3%A3o
http://multisites.ipma.pt/newa/pagina-exemplo/about
http://winds.fe.up.pt/wiki/doku.php

II. EOL Sounding File Format and Data Specifics

https://www.eol.ucar.edu/system/files/files/observing_facility/AVAPS%20Dropsonde%20System/v4.EOL%20Sounding%20Data%20File%20Format.docx

III. Data Quality Control Process

1) Profiles of raw temperature, relative humidity, wind speed, and ascent rate versus pressure are examined to determine if there are problematic sounding files, which could be a result of malfunctioning of the launch detect, sounding system lock-up (a result of weakening of the radiosonde signal in flight), sensor failure, sensor offsets or biases, and slow radiosonde ascent rates (can result in RH errors). Corrections are made where possible to address these

specific problems. Figure 3 shows the frequency distribution of the mean calculated ascent rates (dz/dt).

2) Scatter plots of the raw data are created to check differences in pressure, temperature and RH between independent surface met measurements and the last available surface radiosonde measurement before launch. These plots enable us to evaluate the magnitude of radiosonde pressure biases and they allow us to determine if large diurnal differences in temperature and relative humidity vs Local Standard Time (LST) exist as a result of daytime solar heating of the unventilated radiosonde sensors.

3) All altitudes are initialized to the correct surface heights. A correction was applied to the GPS altitude to address a systematic bias, of approximately 68 meters, that resulted from the sounding system reporting ellipsoid heights. For more information please see #4 under 'Overview of Issues'.

4) All sondes launched by NCAR were passed through the Vaisala required GC25 ground check unit. This ground check uses a reference temperature sensor to recalibrate the radiosonde temperature. A reference pressure measurement, obtained from an independent pressure sensor, is used for the pressure correction, and a desiccant is used to test the RS92 humidity sensors at near zero percent relative humidity.

   The comparison of the radiosonde temperature sensor with the GC25 reference temperature sensor provides a temperature offset correction (Table 2), which is applied following the method used by Vaisala. If no GC25 reference temperature is available the median correction value from sondes with a GC25 reference temperature measurement is used.

   A ratio of the reference pressure measurement to the sonde pressure measurement (Pref/Psonde) at the surface provides a pressure offset correction (Table 2), which is also applied following the method used by Vaisala. If no reference pressure measurement is available the median correction value from all soundings with a reference pressure is used. The reference pressure is part of the independent surface met station. Unfortunately, during Perdigao the collection of data from the surface met sensors at the sounding site was inconsistent during operations. As a result, fifty-one sounding files did not contain surface reference measurements (see #1 and #2 under 'Overview of Issues'). In order to correct this issue, pressures measured from the nearest ISFS flux tower (TSE10) were adjusted to the altitude of the sounding site and used as reference pressure for the correction. The TSE10 site was located at 39°42'42.88"N and 7°44'0.29"W, and the surface height was 333.76 meters (MSL). The sounding system height was 312.12 meters (MSL), so the pressure required an altitude adjustment of 21.64 meters. These computed pressure values were entered into the surface met data line for all of the sounding files.

   The humidity reading in the GC25 ground check unit was only used to verify the proper functioning of both humidity sensors. This method follows the procedures established by the GCOS Reference Upper Air Network (GRAUN).

5) All temperature measurements are corrected for a solar and infrared radiation error using the Vaisala radiation correction table RSN2010 and the solar angle and pressure at time of

measurement.

6) All daytime soundings have been corrected for the Vaisala RS92 dry bias (Vömel et al. 2007). This correction adjusts the observations for the fact that the Vaisala RS92 humidity sensors are heated by the sun during daytime, and as a result report humidity values that are biased low. The NCAR correction algorithm has been described by Wang et al. (2013).

7) The bias corrected soundings are processed through Batch ASPEN, which analyzes the pressure, temperature, relative humidity and GPS wind data, performs smoothing, and filters out suspect data points.
For more information on ASPEN or to download the software please visit: http://www.eol.ucar.edu/software/aspen

8) Profiles of quality controlled temperature, RH, wind speed, and wind direction versus geopotential altitude are examined. These enable us to visually evaluate the final data product for outliers, or any other obvious problems that may have previously gone undetected.

IV. Overview of issues

Performing the quality control procedures outlined above allows us to identify and, in many cases, resolve issues that could potentially impact research performed using these data sets.
The following issues, noted in Table 1, were found. The mean magnitude of the corrections and standard deviations are shown in Table 2. Where necessary, corrections have been applied. Following the table are more detailed descriptions of the data quality issues discovered and information on how they were addressed.

Table 1 – Summary of Data Quality Issues Found

Data Quality Issue	# of soundings
No Surface Met	51
Missing GC25 data	13
Early Launch Detects	3
Late Launch Detects	4
Bad RH Sensor	5
Early Loss of Data	4
Erratic Behavior	2
Telemetry Gaps	2

Table 2 – Mean magnitude and standard deviations of the pressure and GC25 temperature corrections applied to soundings

Mean Pressure Correction Factor	1.00106
Std Dev	0.00061
Mean GC25 Temperature Correction (K)	-.02378

Std Dev around mean temperature **(K)**	0.19040

1. **No Surface Met Data –** The sounding files listed in Table 3 contained no reference surface meteorological data in either the raw or preliminary quality controlled data files, but instead contained measurements transferred from the radiosonde. Surface pressures were obtained from the closest Integrated Surface Flux System tower (TSE10), which was located 335 meters southeast of the sounding site. The surface pressures from TSE10 were adjusted (upward), using the hypsometric equation, to account for a 21.6 meter elevation difference between the two sites. The adjusted surface pressures are contained in the first data line of the quality controlled files and were used in the surface pressure correction. In order to be consistent, all surface pressure measurements for all soundings were replace with TSE10 adjusted surface pressure.

Table 3 – Raw and Preliminary QC Sounding Files with Missing Surface Pressure

D20170501_112116_P.1	D20170506_050829_P.1	D20170510_171300_P.1
D20170501_171431_P.1	D20170506_111138_P.1	D20170510_230740_P.1
D20170502_050901_P.1	D20170506_170744_P.1	D20170511_051005_P.1
D20170502_111516_P.1	D20170506_230607_P.1	D20170511_111009_P.1
D20170502_170559_P.1	D20170507_050533_P.1	D20170525_112332_P.1
D20170502_230808_P.1	D20170507_110642_P.1	D20170526_171851_P.1
D20170503_051025_P.1	D20170507_171414_P.1	D20170527_110855_P.1
D20170503_171252_P.1	D20170507_231005_P.1	D20170527_170328_P.1
D20170503_231109_P.1	D20170508_050805_P.1	D20170527_201035_P.1
D20170504_050755_P.1	D20170508_110841_P.1	D20170607_230612_P.1
D20170504_111550_P.1	D20170508_171048_P.1	D20170614_170637_P.1
D20170504_170713_P.1	D20170508_230957_P.1	D20170614_210359_P.1
D20170504_231614_P.1	D20170509_051225_P.1	D20170614_231143_P.1
D20170505_051410_P.1	D20170509_171234_P.1	D20170615_045910_P.1
D20170505_111149_P.1	D20170509_232424_P.1	D20170615_090007_P.1
D20170505_170529_P.1	D20170510_051441_P.1	D20170615_112158_P.1
D20170505_230843_P.1	D20170510_111414_P.1	D20170615_171127_P.1

2. **Missing Ground Check Correction Information -** All radiosondes listed in Table 4 were missing information needed for the GC25 ground check unit pressure and temperature correction. These were corrected using the median temperature offset and median pressure offset correction of all radiosondes, which were passed through the ground check. With this correction applied to all sondes, the mean bias of the entire set of radiosondes has been removed. However, the sondes which were not passed through the GC25 ground check unit may have a small random offset, which follows the distribution established by the properly recalibrated sondes.

Table 4 – Soundings with Missing Ground Check Information

D20170501_112116	D20170502_230808	D20170504_170713
D20170501_171431	D20170503_051025	D20170506_170744
D20170502_050901	D20170503_171252	D20170509_171234
D20170502_111516	D20170503_231109	
D20170502_170559	D20170504_050755	

3. **Launch Detect Errors** The soundings listed below experienced errors with the automatic launch detect. Early launch detect files, shown in the Table 5, are caused by an abrupt decrease in pressure while the radiosonde is still on the ground. Data collected by the radiosonde before launch is incorrectly flagged as 'in-flight' data and the time stamp associated with the launch time is incorrect. All early launch detect soundings have been corrected to reflect the actual time of launch at time of release. The preliminary quality controlled data (version 0.1), released just following the project, contain missing data below the height where the sounding system incorrectly detected launch; however, for version 1.0 the complete profiles have been restored.

   Late launch detect filenames are shown in Table 6. Late launch detects occur most often when the sonde is not able to collect a sufficient amount of surface data prior to launch (also known as "rushed launches") or the operator fails to complete all steps of the sounding system software before launch. The result is a delay in the launch detect mechanism, which relies on change in pressure to determine when the balloon release occurs. Three files indicated with an asterisk are soundings that lost near surface data which was unable to be recovered. The filenames and launch times indicated in those files reflect the time when recording of the data began, not the actual time of release.

Table 5 - Soundings with Early Launch Detect Errors

Radiosonde ID	Original and Preliminary QC Filename	New Filename
144873104	D20170527_151519	D20170527_143111
144873109	D20170527_233345	D20170527_230315
145033333	D20170609_174546	D20170609_174610

Table 6 - Soundings with Late Launch Detect Errors

Radiosonde ID	Original Filename	New Filename	First sounding pressure data collected

171323453	D20170510_111414	D20170510_111344	No data loss
131453527	D20170529_232634*		897 hPa
144953330	D20170609_171245*		931.02 hPa
144933366	D20170612_052022*		948.80 hPa

*****Soundings did not contain prelaunch data and filenames did not change

4. **GPS Altitude Correction –** A systematic bias on the order of approximately 68 meters was found in the GPS altitudes measured by the radiosondes. It is suspected that this is a result of the measurement failing to account for the geoid altitude at the launch site, which is 56 meters. The sounding GPS altitudes were all adjusted accordingly. The vertical accuracy of the GPS sensors is +/- 20 meters.

5. **Bad RH** – The following soundings (Table 7) were found to have questionable relative humidity profiles due to a damaged sensor. The result is an offset between the two hygrometers measuring humidity. The first file, D20170528_230701, reached saturation and was therefore deemed correctable because the biased sensor could be identified. For that profile, measurements from the RH2 sensor were scaled back by a factor of 1.04 to bring the two sensors into agreement (Figure 5). The other radiosondes did not encounter saturation, so no correction could be applied. The uncertainty of those measurements is equivalent to the offset provided in the table.

Table 7 - Soundings with Broken RH Sensors

Filename	Offset between RH1 and RH2 (%)
D20170528_230701	~4.0
D20170531_170820	~1.0
D20170601_171231	~2.0
D20170602_111308	~1.5
D20170606_231057	~2.0

6. **Early Loss of Data** – Four sounding files listed in Table 8 ended prematurely (below 5 km) as a result of radiosonde failure. See Figure 4 for the ceiling heights of all Perdigao soundings. One file, D20170613_112424, lost only GPS wind and location data at 2.3 km, but contains the complete profiles for pressure, temperature, RH and dewpoint temperature.

Table 8 - Soundings with Premature Data Loss

Filename	**Sounding Duration (min)**	**Last Acquired GPS Altitude (m)**
D20170512_051405	2.75	637.55
D20170515_230316	15.53	3719.21
D20170609_171245*	6.12	3040.61
D20170613_112424	6.9 (GPS loss only)	2268. 55
D20170614_051618	16.15	4603.46

*A second radiosonde was launched at 174610 UTC.

7. **Erratic Behavior –** Radiosonde, , had an unstable pressure sensor which produced erratic measurements for short periods during the sounding. That was resolved by applying a monotonic pressure filter to the data. The radiosonde, D20170512_051405, experienced erratic balloon behavior. It rose to the height of the mountain ridge, briefly descended, and then drifting horizontally for a time before the signal was lost. Profiles of the hydrostatically calculated ascent rates are shown in (Figure 6).

8. **Telemetry Gaps –** Two soundings, noted in Table 9, had poor telemetry that caused sporadic gaps of missing data which resulted in missing geopotential altitudes. The maximum interpolation interval in ASPEN is set to 60 seconds, and is not currently configurable, so in cases where pressure is lost for longer than 60 seconds, geopotential altitude will not be computed above that height.

Table 9 – Early Loss of Geopotential Altitude

Filename	Highest Computed Geopotential Altitude (m)	Last Acquired Pressure Measurement (hPa)
D20170526_051238	3017.2	365.3
D20170611_050755	421.9	51.7

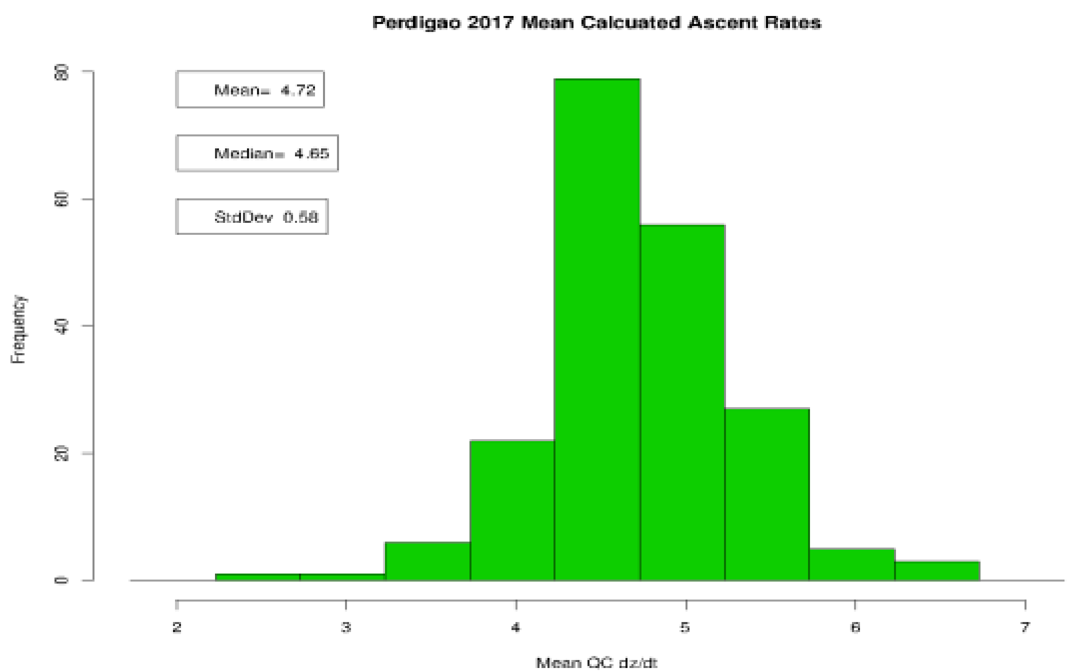

Figure 3 - Frequency distribution of mean calculated ascent rates of all soundings collected during the Perdigao field campaign.

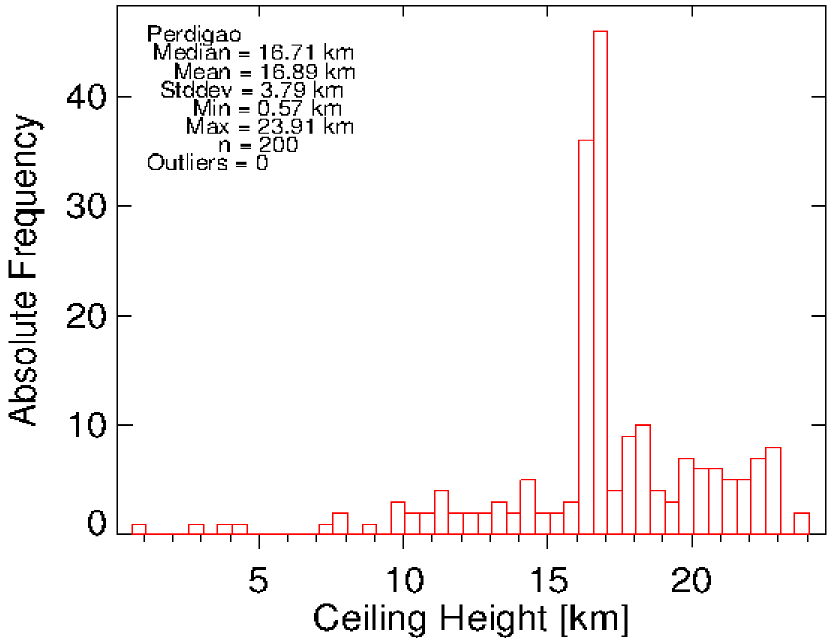

Figure 4 - Frequency distribution of the ceiling heights for all soundings. Four soundings ended prematurely (below 5 km) due to sonde failure. The peak values at 17 km were a result of operational procedures where the soundings were terminated at 100 hPa.

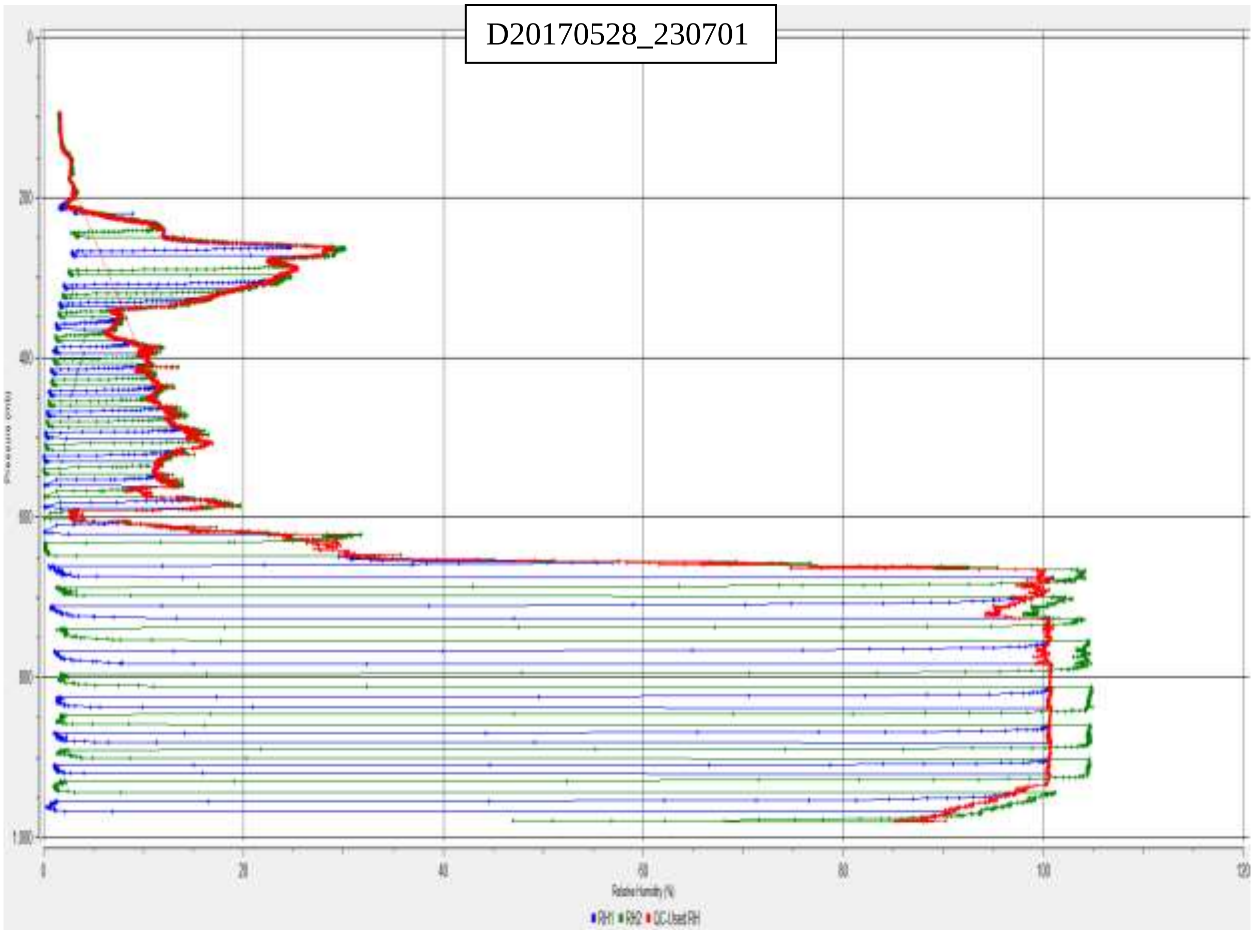

Figure 5 - Profile of sounding D20170528_230701 shows an offset, in one of two hygrometers, of approximately 4%. The magnitude of the offset is considerably larger in saturated conditions, than aloft in the drier environment. This sounding was corrected by scaling back RH2 by 1.04. The green line represents RH2 values before correction. The red line shows the final QCed RH merged from the RH1 and (corrected) RH2 sensors.

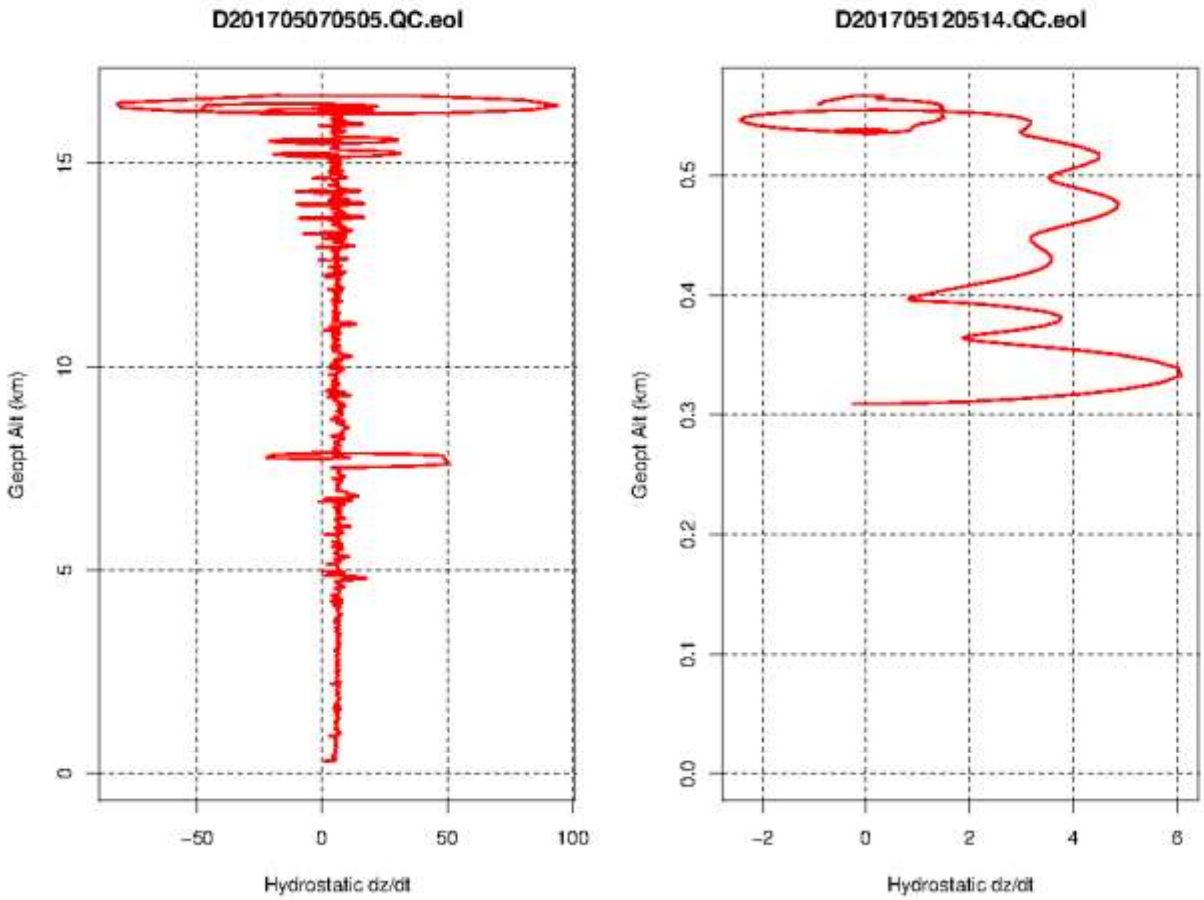

Figure 6 - Profiles of hydrostatically computed dz/dt from two sondes, D20170507_0505 and D20170512_0514. The profile on the left reveals an issue with the sondes pressure sensor that was resolved by applying a monotonic pressure filter. The radiosonde shown on the right rose to the height of the mountain ridge, briefly descended, and then drifting horizontally for a time before the signal was lost.