## Dynamics of the Madden-Julian Oscillation

# DYNAMO 2011-2012 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 or plots from this document are used for publication or presentation purposes, please provide appropriate acknowledgement to NSF and NCAR/EOL and make reference to Young et al. (2012, J. Wang, W. Brown and D. Lauritsen: DYNAMO 2011 quality controlled RV Revelle radiosonde data set.)*

# Dynamics of the Madden-Julian Oscillation (DYNAMO) 2011 Quality Controlled Radiosonde dataset from RV Revelle

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| 1.2 | 02/03/2013 | *K. Young* | Correction to 29 soundings with extreme (incorrect) surface met winds |

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# I. Dataset Overview

Dynamics of the Madden-Julian Oscillation (DYNAMO) was a field campaign aimed at examining and improving upon the modeling of key processes of the Madden-Julian Oscillation (MJO); which is thought to considerably influence weather and climate. The project was conducted in the tropical Indian Ocean during the Fall 2011 and Spring 2012. It employed the use of numerous atmospheric instruments including; multiple radar, land and ship based radiosonde sounding systems, as well as NCAR GAUS radiosonde systems on the island of Diego Garcia and the Ship R/V Revelle (Fig. 1). A total of 636 quality controlled soundings, collected between August 29, 2011 and February 10, 2012, are contained in the final DYNAMO RV Revelle data set (Fig 2).

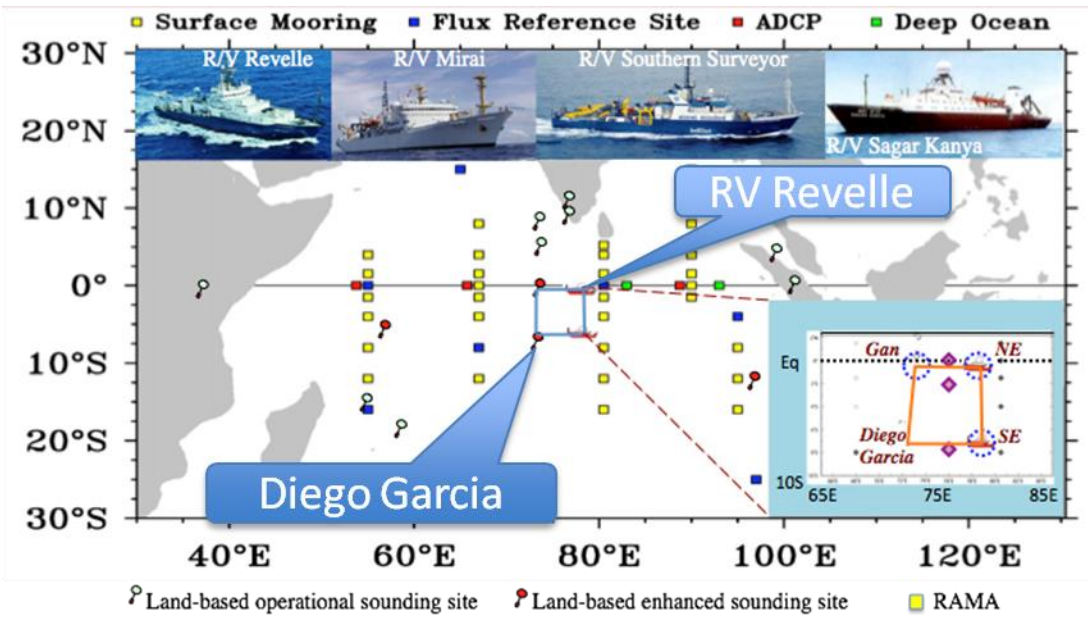


Fig. 1 Map of DYNAMO field campaign domain with instrument sites, including soundings sites. (adopted from DYNAMO project page: http://www.eol.ucar.edu/projects/dynamo)

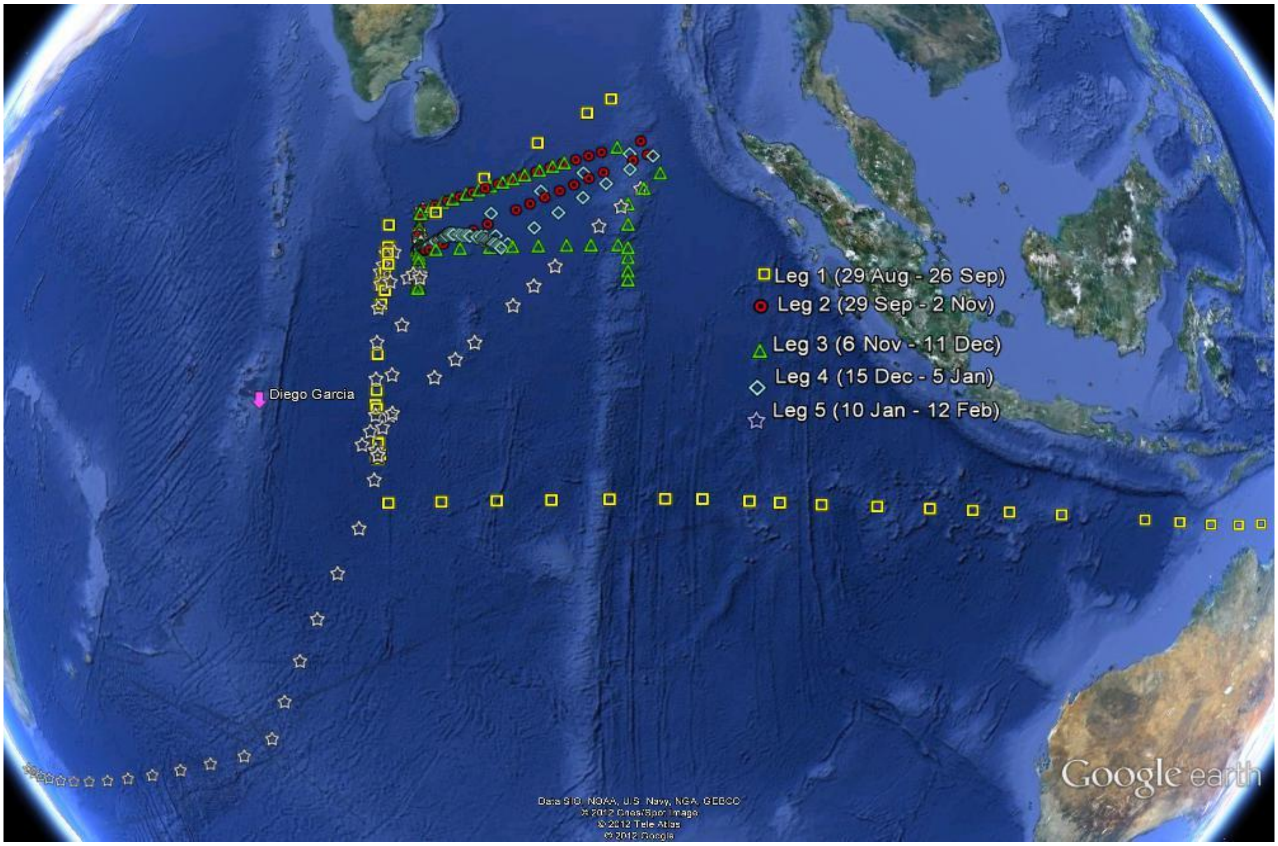


Fig. 2 Map of RV Revelle research cruises. Each color represents a different leg of the project and each dot represents a radiosonde launch location.

## II. EOL Sounding File Format and Data Specifics

The EOL format is an ASCII text format that includes a header (Table 1), with detailed project and sounding information, and seventeen columns of high resolution data (Table 2). The "QC.eol" files are one-second resolution data files with appropriate corrections and quality control measures applied. The naming convention for these files is "D", followed by "yyyymmdd_hhmmss_P.1.PreCorr.SRDBcorr.QC.eol" where yyyy = year, mm = month, hh = hour of the day GMT, mm = minute of the hour, ss = second of the hour (which refer to the launch time of the sonde), and "QC.eol" refers to the EOL file format type.

The header contains information including data type, project name, site location, actual release time, and other specialized information. The first seven header lines contain information identifying the sounding. The release location is given as: lon (deg min), lon (dec. deg), lat (deg min), lat (dec. deg), altitude (meters). Longitude in deg min is in the format: ddd mm.mm'W where ddd is the number of degrees from True North (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 following three header lines contain information about the data system and auxiliary information and comments about the sounding. The last 3 header lines contain header information for the data columns. Line 12 holds the field names, line 13 the field units, and line 14 contains dashes (--- characters) signifying the end of the header. Data fields are listed below in Table 2.

The files contain data calculated at one-second intervals. The variables pressure, temperature, and relative humidity are calibrated values from measurements made by the radiosonde. The dew point is calculated from the relative humidity and temperature. The geopotential altitude is calculated from the hydrostatic equation using pressure, temperature, and relative humidity. The rate of ascent is calculated from pressure. The radiosonde position (lat, lon, GPSAlt) and winds are measured by use of a GPS receiver in the sonde. The raw wind values are subjected to a digital filter to remove low frequency oscillations due to the sonde pendulum motion beneath the balloon when run through NCAR's Atmospheric Sounding Processing ENvironment (ASPEN) software. The quality of the GPS altitude is somewhat questionable. The accuracy of the sensor is typically +/-20 m, and may show large variability. For this reason, investigators are encouraged to use geopotential altitude over GPS altitude.

## Table 1 - EOL Sounding File Format (dropsonde and radiosonde)

```
Data Type/Direction:                    GAUS SOUNDING DATA/Ascending
File Format/Version:                    EOL Sounding Format/1.1
Project Name/Platform:                  DYNAMO/NCAR GAUS
Launch Site:                            Revelle_20111020
Launch Location (lon,lat,alt):          80 32.53'E 80.542160, 0 04.47'N 0.074508,    19.00
UTC Launch Time (y,m,d,h,m,s):          2011, 10, 20, 02:16:47
Sonde Id/Sonde Type:                    001850710/Vaisala RS92-SGP (ccGPS)
Reference Launch Data Source/Time:      Campbell Scientific CR10/02:16:38.00
Original Sfc Met Obs:                   Pres =  1009.56 (mb) Temp = 26.81 (degC)  RH = 82.53 (%)
Post Processing Comments:               Aspen Version 3.1; Created on 25 Oct 2012 19:33 UTC; Configuration upsonde-1s
/
  Time   -- UTC  --    Press    Temp   Dewpt     RH    Uwind   Vwind    Wspd     Dir      dZ  GeoPoAlt      Lon         Lat       GPSAlt  Wwind  Wwind_f
   sec   hh mm   ss     mb       C       C        %     m/s     m/s      m/s     deg     m/s      m        deg         deg          m      m/s     m/s
-------- -- -- ----- ------- ------- ------- ------- ------- ------- ------- ------- ------- -------- ----------- ----------- -------- ------ --------
```

## Table 2 - Lists data fields provided in the EOL format ASCII soundings

| Field No. | Parameter | Units | Measured/Calculated |
|---|---|---|---|
| | | | |
| 1 | Time | Seconds | ------------- |
| 2 | UTC Hour | Hours | ------------- |
| 3 | UTC Minute | Minutes | ------------- |
| 4 | UTC Second | Seconds | ------------- |
| 5 | Pressure | Millibars | Measured |
| 6 | Dry-bulb Temp | Degrees C | Measured |
| 7 | Dewpoint Temp | Degrees C | Calculated |
| 8 | Relative Humidity | Percent | Measured |
| 9 | U Wind Component | Meters/Second | Calculated |
| 10 | V Wind Component | Meters/Second | Calculated |
| 11 | Wind Speed | Meters/Second | Measured |
| 12 | Wind Direction | Degrees | Measured |
| 13 | Descent Rate | Meters/Second | Calculated |
| 14 | Geopotential Altitude | Meters | Calculated |
| 15 | Longitude | Degrees | Measured |
| 16 | Latitude | Degrees | Measured |

| | | | |
|---|---|---|---|
| 17 | GPS Altitude | Meters | Measured |

## III. Data Quality Control Process

**1.** Profiles of raw temperature, relative humidity, wind speed and ascent rate versus pressure are first 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 sonde signal in flight), sensor failure, sensor offsets or biases, and slow radiosonde ascent rates. Corrections are made where possible to address these specific problems.

**2.** All of the soundings were adjusted to a consistent surface height. When set to mobile mode, the sounding system depends on the GPS sensor to capture accurate surface heights. During post-processing, those heights are converted to geometric height and used with latitude to compute surface geopotential height. The Revelle soundings were found to have inconsistent GPS measurements with large variability, and a disparity in sensor location heights between the radiosonde and an independent surface met sensor, used as reference to evaluate radiosonde data quality, was problematic as well. To correct this, the surface geometric heights were set to 19 meters above mean sea level (MSL); the height at which the surface met sensor was located, and the radiosonde data was interpolated to that height. The interpolated pressure (Fig 3), temperature and RH values were then entered into the last available prelaunch sounding data lines and used in the pressure correction described in step 3. After the initial release of the quality controlled data it was decided, collectively by the PI's, that in order to address ship surface induced heating on both the sonde and surface-met measurements, that surface met measurements of T and RH should be replaced with sounding data interpolated to the height of the surface met station (19 meters). Dew point temperatures at this height, using the new T/RH values, were recomputed. The original surface met measurements have been added to the header of the sounding data files.

**3.** A pressure ground check (GC) correction is applied to the entire profile for each sounding. The surface pressure measured by an independent surface sensor is used as a reference for the correction. The corrected pressure $P = P^{RS} * P_0^{REF} / P_0^{RS}$, where $P^{RS}$ is the pressure measured by radiosonde, $P_0^{REF}$ is the ground check pressure as indicated by the reference sensor, and $P_0^{RS}$ is the ground check pressure as indicated by the radiosonde on the ground.

**4.** All soundings are then subjected to a radiation correction, applied to the temperature measurements, that takes into account the solar angle at time of launch and removes solar heating that could skew the temperature measurements.

**5.** A daytime radiation dry bias correction is applied to soundings collected during daytime . The correction is adopted from Wang et al. (2012) and is a function of pressure, temperature, humidity and the solar elevation angle. *Wang, J., L. Zhang, A. Dai, F. Immler, M. Sommer and H. Voemel, 2012: Radiation dry bias correction of Vaisala RS92 humidity data and its impacts on historical radiosonde data. J. Atmos. Oceanic Technol.,accepted.*

**6.** Scatter plots of the raw data are created to check differences in pressure, temperature and RH between the surface met and the last available surface radiosonde measurement before launch to find systematic biases in the radiosonde data.

**7.** The raw soundings are processed through ASPEN, which analyzes the data, performs smoothing, and removes suspect data points.

**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. Special Problems to Note (Important Information for Users)

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 were found, and where necessary, corrections were applied:

1. Six sounding files listed below were classified as "slow-ascent soundings" and may have problematic RH profiles that contain artificial "dry spikes" that can be attributed either to under-filling of the balloon with helium or icing of the balloon. Artificial dry spikes occur most often in moist environments when the hygrometers are not sufficiently ventilated due to slow ascent rates (below 3 m/s). In these cases, the RH sensors are unable to reach equilibrium with the environment before turning back on (after heating). Four of the files were corrected by applying additional filtering to layers where the obvious spikes occurred (Fig 4). All of these soundings were processed through ASPEN with slightly more restrictive quality control parameters applied than those typically used for radiosondes. Fig. 4 shows that such adjustment successfully removed the dry spikes. Despite these additional measures, we want to caution data users that the RH data may still contain errors and may not accurately reflect true environmental conditions.

| Slow Ascent Soundings | |
|---|---|
| D20111017_171509 | D20111029_081500 |
| D20111022_171501 | D20111112_021327 |
| D20111027_171926 | D20111201_170629 |

2. Eleven of the radiosondes encountered either vertical downdrafts or balloon icing that caused descent of the balloon package for a period of time during flight. These files were processed through ASPEN with slightly more restrictive quality control parameters applied than those typically used for radiosondes. The additional filtering (performed using ASPEN) removes excessive noise that may be present in the pressure, temperature and RH. **One important thing to note; because ASPEN can only handle monotonically changing pressure, it removes any portion of the file where the radiosonde experiences increasing changes in pressures. As a result, data acquired during descent are set to missing.**

| Downdraft/Iced Soundings | |
|---|---|
| D20111015_201909_P.1 | D20111028_021535_P.1 |
| D20111027_141503_P.1 | D20111117_171302_P.1 |

| | |
|---|---|
| D20111109_234432_P.1 | D20111122_051026_P.1 |
| D20111119_021228_P.1 | D20111124_232132_P.1 |
| D20111124_110817_P.1 | D20111220_052936_P.1 |
| D20111125_111018_P.1 | |

3. The soundings listed below experienced errors with the automatic launch detect. Early launch detect files are shown in the first table and are most often caused by a small, yet abrupt decrease in pressure (listed in normal font). The remaining early launch detect soundings (listed in bold font) experienced very large, abrupt increases/offsets in pressure that incorrectly triggered the launch detect. The cause of the pressure changes is still under investigation. All early launch detect soundings have been corrected to reflect the actual time of launch at time of release.
   Late launch detect filenames are provided in the second table shown below. 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. **Eleven 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, and not the actual time of release. Additionally, because of the absence of prelaunch radiosonde data, these files did not receive the ground check pressure correction.**

| **Early Launch Detects** | |
|---|---|
| **Original Filename** | **New Filename** |
| D20110912_231753 | D20110912_232056 |
| D20111003_052509 | D20111003_052956 |
| D20111021_051641 | D20111021_051642 |
| D20111021_081502 | D20111021_081503 |
| D20111110_234300 | D20111110_234301 |
| D20111118_231014 | D20111118_231416 |
| D20111122_110423 | D20111122_110929 |
| D20111123_110331 | D20111123_110856 |
| D20111127_080350 | D20111127_080902 |
| **D20110830_232300** | **D20110830_232544** |
| **D20110902_131928** | **D20110902_132105** |
| **D20110903_111503** | **D20110903_111809** |
| **D20110904_111710** | **D20110904_111907** |
| **D20110904_231554** | **D20110904_231701** |
| **D20110909_231417** | **D20110909_231530** |
| **D20110919_231449** | **D20110919_231612** |
| **D20110920_231610** | **D20110920_231725** |
| **D20111010_021358** | **D20111010_021908** |
| **D20111018_110317** | **D20111018_111500** |
| **D20111115_021140** | **D20111115_021223** |
| **Late Launch Detects** | |
| **Original Filename** | **New Filename** |
| D20111004_005207 | D20111003_232026* (117 mb) |
| D20111027_021715 | No rename required* (63 mb) |

| | |
|---|---|
| D20111110_202335 | D20111110_201328 |
| D20111112_050908 | D20111112_050905 |
| D20111113_185524 | D20111113_175109* (127 mb) |
| D20111113_204609 | D20111113_202401* (85 mb) |
| D20111114_000049 | D20111113_232423* (66 mb) |
| D20111114_051225 | also a sounding system lockup* |
| D20111118_192705 | D20111118_173459* (64 mb) |
| D20111122_021832 | D20111122_021826 |
| D20111123_112507 | D20111123_110331 |
| D20111124_001806 | D20111123_231038* (46 mb) |
| D20111130_231445 | No rename required* (150 mb) |
| D20111216_123342 | D20111216_114347* (72 mb) |
| D20120112_000107 | D20120111_233100* (61 mb) |
| D20111112_020742 | D20111112_021327 |

*indicates soundings with incorrect launch times because actual time of launch could not be determined. The number in parentheses, following the filename indicates the number of millibars of near surface data lost. Files also contained no prelaunch radiosonde data, and therefore could not receive the ground check pressure correction.

4. One file, D20110916_112109, contained no surface met data and therefore could not receive the ground check pressure correction.

5. Two files contained data from the same sonde. File D20111122_221306_P.1 was actually launched on 11/23/2011 at 172808 UTC. The sonde signal weakened and then was lost. The system was restarted and the signal was reacquired some time later, with the data being stored in a separate sounding file, D20111123_183242_P.1. The two files were concatenated into one and renamed D20111123_172808.

6. The following sounding files needed repair because they experienced sounding system lock-up caused by weakening or loss of the radiosonde signal. The original sounding files were not saved in the correct format or to the correct file names. They contained no LAU (launch) or A00 (surface met) data lines, and were missing the standard 19 line tail at the end of the raw data file; all things necessary in order for ASPEN to run properly. Data before the lock-up was preserved, however anything measured by the radiosonde after the lock-up was lost. Filenames for these soundings were changed to reflect the actual launch time, determined by pressure change and GPS dz/dt, and surface met data collected just prior to launch was retrieved and entered into the sounding files.

| **New Filenames with Corrected Launch Times** | |
|---|---|
| D20110901_111741 | D20110905_231702 |
| D20111013_023557 | D20111013_171512 |
| D20111110_021444 | D20111110_111310 |
| D20111114_051225 | D20111117_231448 |
| D20111128_080739 | D20111218_113342 |
| D20111224_060520 | D20111226_114102 |

7. Seven soundings were characterized with excessive noise in the pressure, temperature and RH data. One of those, indicated with an asterisk was also a downdraft sounding. There appears to be no systematic cause for

the noisy data, however in order to minimize it, these files were processed through ASPEN with slightly more restrictive quality control parameters applied than those typically used for radiosondes.

| Sounding with Excessive Noise (PTU) |
|---|
| D20111005_141931* |
| D20111017_141811 |
| D20111015_201909 |
| D20111024_171643 |
| D20111028_051551 |
| D20111110_234301 |
| D20111113_175109 |

* Sounding also had period of time where the balloon descended, also referred to as a downdraft sounding.

8. Thirty three files were corrected for a small increasing spike in temperature, which is suspected to be caused by the radiosonde traveling through the ships smoke plume. These values were corrected by setting the artificially heated measurements to missing. This typically occurred 5-10 seconds into the flight and was measured for approximately 1-3 seconds. The profiles were characterized by a sharp and narrow spike in temperature of approximately 1-2 degrees C (Fig 5). The obvious spikes detected were removed during quality control of the data. These files are listed below.
As a cautionary note, the Revelle was stationary for many launches and likely generated a significant heat plume from the intense tropical solar radiation, particularly in light winds. Users should be aware that there may other soundings where the radiosonde passed through this heat plume and experienced warming and drying.

| Sounding Corrected for Artificial Ship Plume Heating | | |
|---|---|---|
| D20110904_111907 | D20111028_171652 | D20111122_172824 |
| D20110917_111800 | D20111030_021746 | D20111126_173259 |
| D20111013_051824 | D20111030_051622 | D20111126_231045 |
| D20111013_111508 | D20111109_201634 | D20111129_231641 |
| D20111013_141744 | D20111109_234432 | D20111206_171723 |
| D20111014_231747 | D20111113_050826 | D20111224_083218 |
| D20111016_051509 | D20111113_081047 | D20120130_111918 |
| D20111016_231712 | D20111117_171302 | D20120130_231531 |
| D20111019_081623 | D20111119_050936 | D20120201_111530 |
| D20111021_021745 | D20111119_201044 | D20120203_111441 |
| D20111028_031407 | D20111122_051026 | D20120207_111525 |

9. Twenty nine files, listed below, contained incorrect surface wind measurements in excess of 40 m/s. For these files, surface wind speed and wind direction (indicated in the line with a time stamp of -1.0 s) were replaced, where available, with quality controlled values measured by the radiosonde at the height closest to (but below) the height of the surface met sensor (19m). The heights, from which the winds were obtained, are noted in the header. Where radiosonde data were not available, surface wind speed and direction were set to missing values.

| **Soundings Corrected for Errors in Surface Met Wind Measurements** | | |
|---|---|---|
| D20111219_054800 | D20111229_053344 | D20111230_203220 |
| D20111220_052936 | D20111229_112441 | D20111230_233351 |
| D20111222_113237 | D20111229_172925 | D20111231_053006 |
| D20111223_052911 | D20111229_233712 | D20111231_112806 |
| D20111225_112824 | D20111230_023357 | D20111231_173114 |
| D20111225_173620 | D20111230_053016 | D20111231_233854 |
| D20111225_233804 | D20111230_083057 | D20120101_054020 |
| D20111226_053147 | D20111230_112723 | D20120101_112454 |
| D20111228_053139 | D20111230_142816 | D20120102_052942 |
| D20111228_112739 | D20111230_172814 | |

10. Three soundings were found to have bad temperature sensors which resulted in a bias of the temperature measurements, compared with other radiosondes launched three hours before and after the soundings. D20111001_231251 contains a cold bias of ~5 degC below 825 mb, D20111109_111146 contains a cold bias of ~5 degC, and D20111126_201706 exhibits a warm bias of ~5 degC. The suspicious temperature data have not been corrected, and have not been set to missing values. These data should be used with caution.

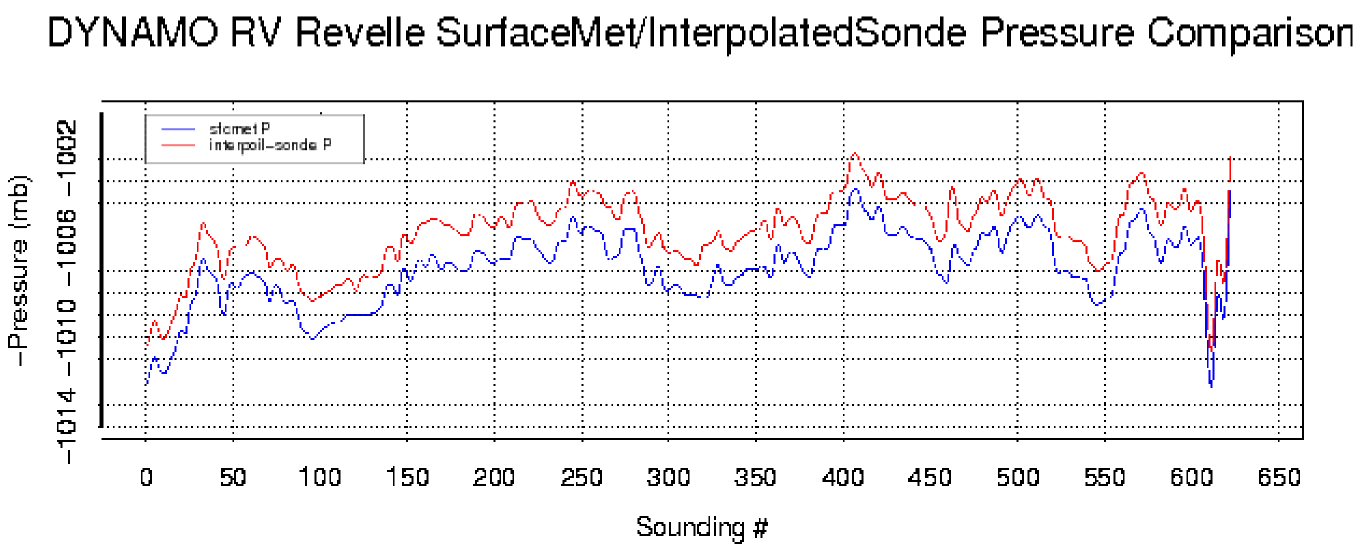


Figure 3. Plot shows surface pressure measured by the surface met station in blue, and pressure of the radiosondes after having been interpolated to the height of the surface met station (19m). The interpolation was performed to address a disparity in sensor location heights. The ~1.5 mb difference between the two lines is consistent with differences seen between radiosondes and surface met at Diego Garcia, and results from a bias found in the Vaisala RS-92 radiosondes. This pressure bias is corrected for when the pressure ground check correction is applied.

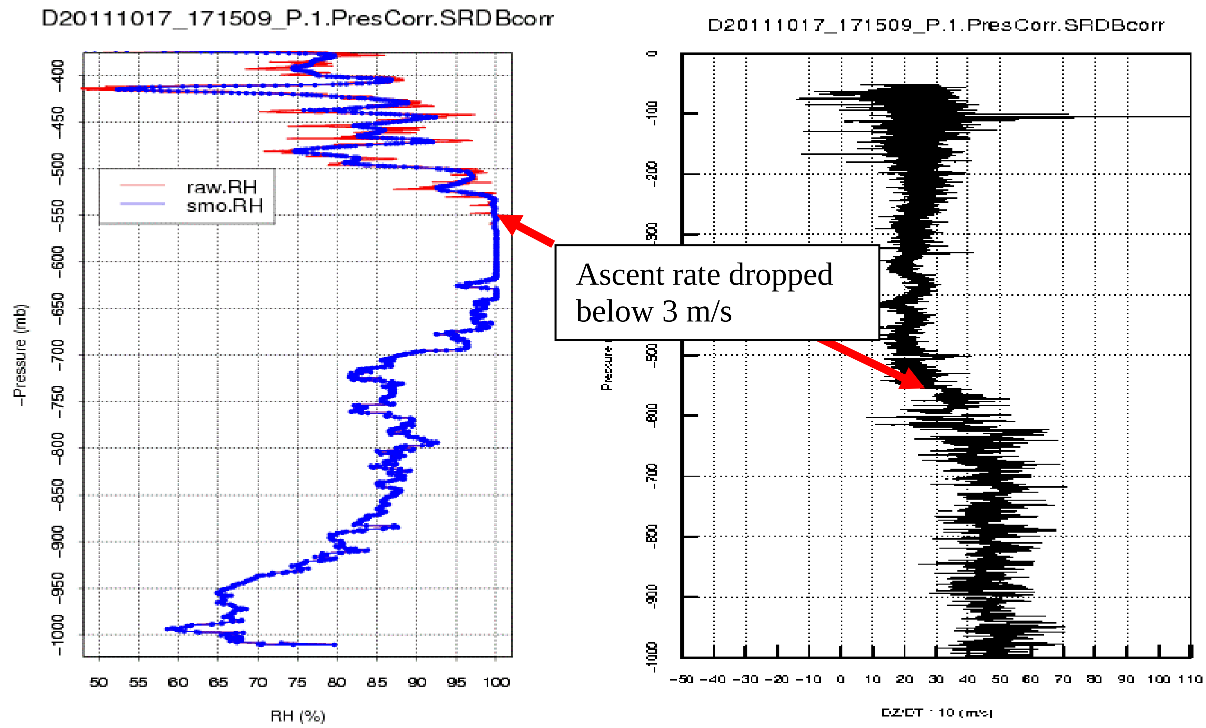


Figure 4 Raw data profiles, for sounding D20111017_1715, show relative humidity (%) on the left, and ascent rate (m/s * 10) on the right. This radiosonde experienced slower than normal ascent rates above 550 mb. All files containing artificial dry spikes, where ascent rates were less than 3 m/s, were subjected to additional filtering.

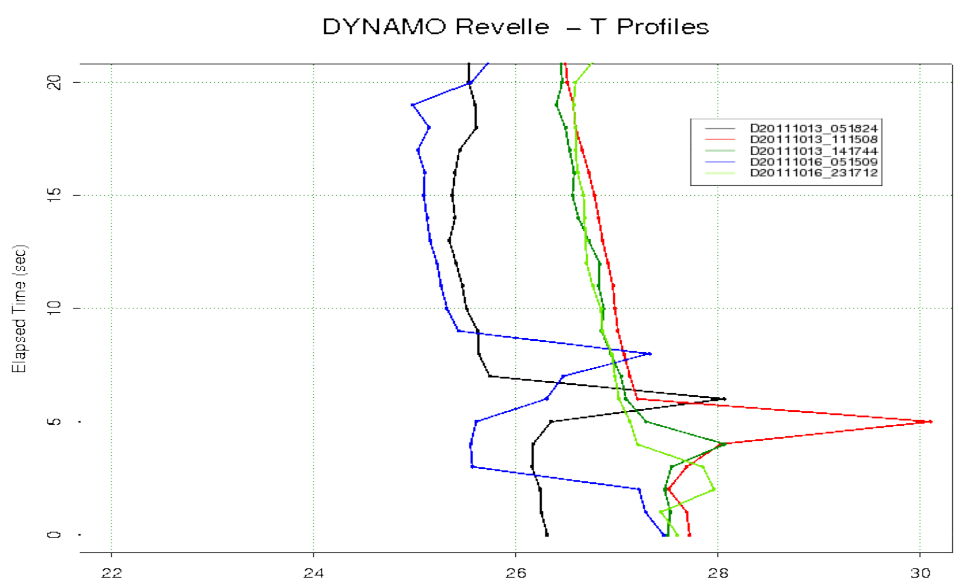


Figure 5 Shown are raw temperature profiles, versus elapsed time, from five radiosonde that were suspected of passing through the ships smoke stack. This caused a brief artificial spike in the temperature of the raw data. These files were corrected and the spikes were removed.