NOAA P-3 Dropsonde High Resolution L3 Data

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1. Data Set Overview

During DYNAMO, 470 GPS Dropsondes were released from the NOAA P-3 (N-43). 469 quality controlled dropsondes are included in the final DYNAMO dropsonde data set. The dropsondes to measure the vertical structure of the atmosphere below the aircraft flight track. During DYNAMO, the dropsondes were mainly used in three ways: (1) to bridge the gap between the DYNAMO array radiosonde sites; (2) to make high resolution measurements in deep convective systems during RCEs, and (3) to make high resolution boundary layer measurements during boundary layer focused missions.

<u>Time period</u>: 12 missions (10 of which were science focused missions) during 11 October – 13 December 2011, as indicated below.

Mission	Number of Dropsondes	Purpose
11/11	5	Instrument/Operation, Convection
11/13	49	Boundary Layer
11/16	55	Convection (ITCZ)
11/19	16	Boundary Layer
11/22	51	Convection (MJO)
11/24	57	Convection (MJO)
11/26	33	Boundary Layer, Revelle fly-over
11/28	35	Boundary Layer
11/30	58	Convection (ITCZ)
12/4	43	Boundary Layer
12/8	54	Convection (Suppressed), coordinate with Falcon and S-Polka
12/13	12	Calibration/Intercomparison, Boundary Layer

<u>Physical location</u>: The aircraft was based out of Diego Garcia (DGAR: 7.3°S, 72.4°E). The missions were conducted within the following geographical area: 14.5°S – 1.2°N, 69.8°E – 80.9°E. The P3 flew at an average altitude of 2 km and reached a maximum of around 8 km.

<u>Data source</u>: Dropsonde data were processed in near real time using the AVAPS (Airborne Vertical Atmospheric Profiling System).

2. Instrument Description

The dropsonde incorporates a new pressure, temperature, humidity sensor module (RSS903) and a new GPS receiver module (GPS111), both designed by Vaisala, Inc., for their RS90 radiosonde.

The sensor specifications are shown in the following table:

Dropsonde Sensor Specifications

	Range	Accuracy	Resolution
Pressure	1080 – 100 hPa	1.0 hPa	0.1 hPa
Temperature	-90 - +60 C	0.2 C	0.1 C
Humidity	0 – 100%	5%	1.0%
Horizontal Wind	0 – 200 m/s	0.5 m/s	0.1 m/s

Additional information is available on the following web sites:

https://www.eol.ucar.edu/content/avaps-aircraft-data-system
https://www.eol.ucar.edu/content/avaps-dropsondes
https://archive.eol.ucar.edu/docs/isf/facilities/dropsonde/

Please consult the attached EOL Dropsonde Project Analysis Summary for more details.

3. Data Collection and Processing

The dropsonde data were processed in near real time using the AVAPS (Airborne Vertical Atmospheric Profiling System) and quality controlled by Falko Judt and Chiaying Lee (UM/RSMAS) using Aspen (Atmospheric Sounding Processing Environment). Additional QC was carried out at EOL by Kate Young and Junhong Wang. The original V1 data were released on 16 February 2012. For V2 (June 2016) a temperature dependent dry bias correction was applied. The final release data (Version 3) were obtained from the EOL DYNAMO catalog, as updated on 27 July 2016.

For the DYNAMO Legacy Data Products (DLDP), the dropsonde data files have been converted from the EOL ASCII format to netCDF, and file names have been made to be more consistent with the rest of the DLDP (see below). Original file names and variable names corresponding to each variable are noted as attributes in the NetCDF file.

4. Data Format

There is one file for each dropsonde, named as follows: aircraft.dgar.p3.dropsonde.2011-MM-DDThh:mm:ssZ.nc, where MM is the month, DD is the day, hh is the hour, mm is the minute, and ss is the seconds. The time stamp is for the release time of the sonde. Data are in CF Convention NetCDF format with variables as follows:

```
dimensions:
        x = 1181 ;
variables:
        float time_offset(x) ;
                time_offset:missing_value = -999.f ;
                time_offset:units = "hour" ;
        float Hour(x) ;
                Hour:missing_value = -999.f ;
                Hour:units = "hour" ;
        float Min(x) ;
                Min:missing_value = -999.f ;
                Min:units = "min" ;
        float Sec(x) ;
                Sec:missing_value = -999.f ;
                Sec:units = "s" ;
        float pres(x) ;
                pres:missing_value = -999.f ;
                pres:units = "hpa" ;
        float tdry(x) ;
                tdry:missing_value = -999.f ;
                tdry:units = "c" ;
        float dp(x) ;
                dp:missing_value = -999.f ;
                dp:units = "c" ;
        float rh(x) ;
                rh:missing_value = -999.f ;
                rh:units = "%" ;
        float u_wind(x) ;
                u_wind:missing_value = -999.f ;
```

```
        u_wind:units = "ms-1" ;
float v_wind(x) ;
        v_wind:missing_value = -999.f ;
        v_wind:units = "ms-1" ;
float wspd(x) ;
        wspd:missing_value = -999.f ;
        wspd:units = "ms-1" ;
float wdir(x) ;
        wdir:missing_value = -999.f ;
        wdir:units = "degree" ;
float ASCRATE(x) ;
        ASCRATE:missing_value = -999.f ;
        ASCRATE:units = "ms-1" ;
float alt(x) ;
        alt:missing_value = -999.f ;
        alt:units = "m" ;
float gpsalt(x) ;
        gpsalt:missing_value = -999.f ;
        gpsalt:units = "m" ;
float lon(x) ;
        lon:missing_value = -999.f ;
        lon:units = "degree" ;
float lat(x) ;
        lat:missing_value = -999.f ;
        lat:units = "degree" ;
float W(x) ;
        W:missing_value = -999.f ;
        W:units = "ms-1" ;
float Wfilter(x) ;
        Wfilter:missing_value = -999.f ;
        Wfilter:units = "ms-1" ;
float theta(x) ;
        theta:missing_value = -999.f ;
        theta:units = "Kelvin" ;
float tv(x) ;
        tv:missing_value = -999.f ;
        tv:units = "Kelvin" ;
float theta_v(x) ;
        theta_v:missing_value = -999.f ;
        theta_v:units = "Kelvin" ;
float theta_e(x) ;
        theta_e:missing_value = -999.f ;
        theta_e:units = "Kelvin" ;
```

5. Data Remarks

The data can be accessed using the myriad of software that is able to interact with NetCDF format files, including ncdump, ncview, Matlab, Python, IDL, and NCL. Consult the user help system within each software package.

6. References

Chen, S. S., B. W. Kerns, N. Guy, D. P. Jorgensen, J. Delanoë, N. Viltard, C. Zappa, F. Judt, C.-Y. Lee, and A. Savarin, 2016: Aircraft observations of dry air, ITCZ, convective cloud systems and cold pools in MJO during DYNAMO: Bull. Amer. Meteor. Soc., 97, 405-423. doi:10.1175/BAMS-D-13-00196.1

Attachment: EOL's Dropsonde Project Analysis Summary.

Dynamics of the Madden-Julian Oscillation (DYNAMO) 2011 Dropsonde Project Analysis Summary

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Document Version Control

Version	Date	Author	Change Description
1.0	02-14-2012	*K. Young*	Initial Document Release
2.0		*K. Young*	A dry bias in the RD94 and mini-dropsonde (NRD94) relative humidity measurements was discovered in data collected from 2010 to present, including all of the HS3 dropsonde datasets. The dry bias is strongly temperature dependent. It is considered small at warm temperatures and it becomes stronger at cold temperatures. This RH dry bias has been corrected. The dropsonde files that have received this correction contain an indicator in the header of the file, 'TDDryBiasCorrApplied'
3.0	9/28/2016	*K. Young*	Dewpoint temperature was recalculated using the corrected RH measurements (V2.0)

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DYNAMO 2011 Dropsonde Project Analysis Summary

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For more information on the NCAR Dropsonde System please visit the following site: http://www.eol.ucar.edu/instrumentation/sounding/dropsonde

Disclaimer: The dropsonde 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, K. Young, J. Wang, T. Hock, D. Lauritsen and C. Martin: DYNAMO 2011 quality controlled dropsonde data set.)

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 Fall 2011 and Spring 2012 (Figure 1). It employed the use of numerous atmospheric instruments including; multiple radar, land and ship based radiosonde sounding systems, as well as an NCAR AVAPS dropsonde system, on board the NOAA P-3 aircraft. From November 9 through December 13, 2011, thirteen research flights were conducted and 470 dropsondes deployed. A total of 469 quality controlled soundings are contained in the final DYNAMO dropsonde data set. A detailed summary of the flights is shown in Table 1.

Table 1 - Summary of Science Flights

Name	Dates	Sondes deployed	Soundings in final archive
Flight 1	Nov 09, 2011	1	1
Flight 2	Nov 11, 2011	5	5
Flight 3	Nov 13, 2011	49	49
Flight 4	Nov 16, 2011	55	55
Flight 5	Nov 19, 2011	16	16
Flight 6	Nov 22, 2011	51	51
Flight 7	Nov 24, 2011	57	57
Flight 8	Nov 26, 2011	33	33
Flight 9	Nov 28, 2011	35	35
Flight 10	Nov 30, 2011	59	58
Flight 11	Dec 04, 2011	43	43
Flight 12	Dec 08, 2011	54	54
Flight 13	Dec 13, 2011	12	12
Total		470	469

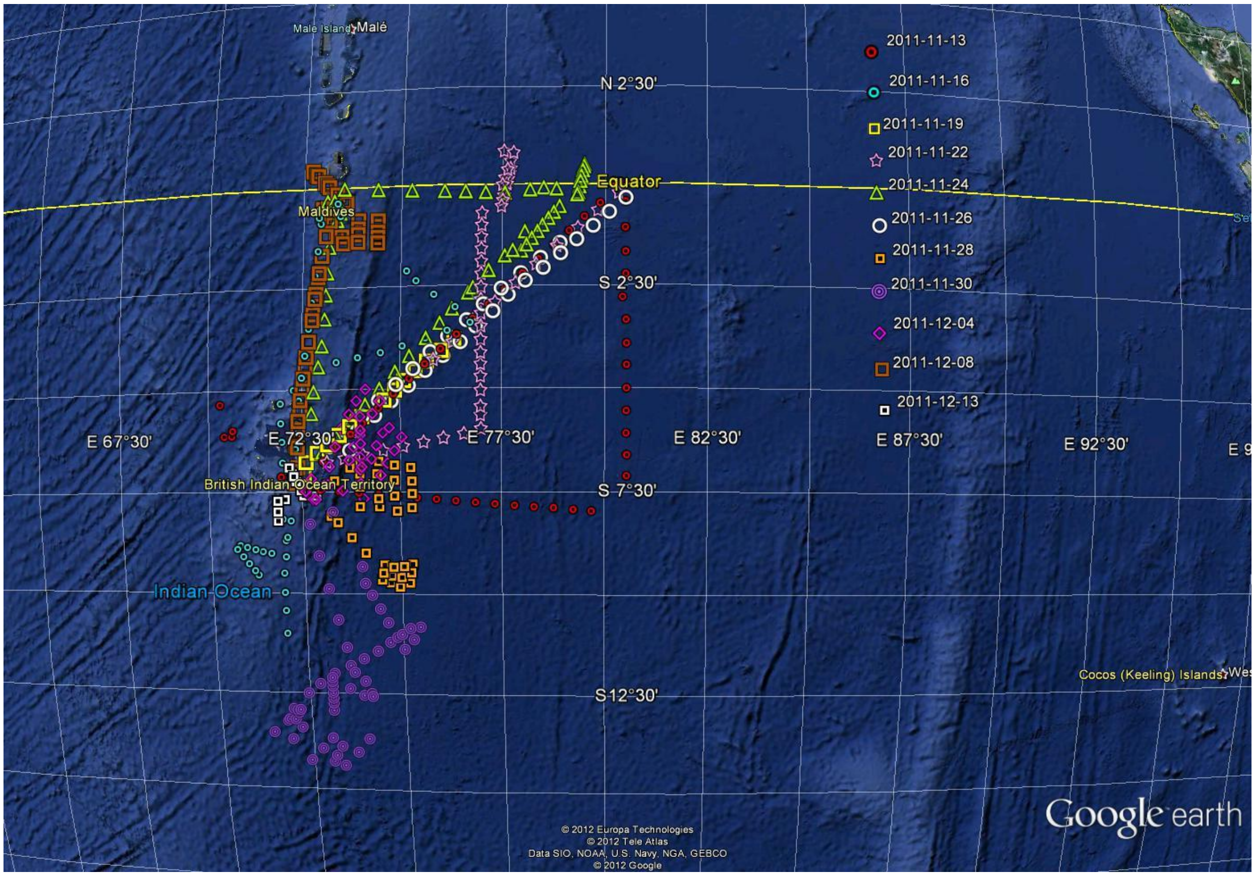

Figure 1- Map of Flights over the Indian Ocean. Each symbol represents one dropsonde location. Different symbols with different colors represent different flights shown in the legend and Table 1.

II. EOL Sounding File Format and Data Specifics

The EOL format is an ASCII text format that includes a header (Table 2), with detailed project and sounding information, and seventeen columns of high resolution data (Table 3). The "QC.eol" files are quarter-second resolution data files with appropriate corrections and quality control measures applied. Note that the thermodynamic data (pressure, temperature and humidity (PTU)) are only available at half-second resolution and wind data is available at quarter-second resolution. The naming convention for these files is "D", followed by "yyyymmdd_hhmmss_PQC.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 3. The last line of the header contains information about the current version of ASPEN and its configuration used for the final data QC. It also contains a flag, 'TDDryBiasCorrApplied', indicating the files have been corrected for a temperature dependent dry bias in the relative humidity measurements (for more information, please see 'Data Quality Control' in Section III).

The variables pressure, temperature, and relative humidity are calibrated values from measurements made by the dropsonde. The dew point is calculated from the relative humidity and temperature. The geopotential altitude is calculated from the hydrostatic equation, typically from the ocean's surface upward. For dropsondes that failed to transmit useful data to the surface, we integrate geopotential altitude from flight level down. The descent rate of the sonde is computed using the time-differentiated hydrostatic equation. The position (lat, lon) and wind data come directly from the GPS sensor. At the request of the projects Principal Investigators the typical EOL file format has been extended to include the vertical wind and filtered vertical wind columns at the end of each record. Vertical wind was computed from the pressure-calculated and theoretical dropsonde fall rates. The filtered vertical winds are the smoothed values. Please note that the vertical wind is first interpolated and then filtered, so the filtered data at lines where the vertical wind is not available should be ignored. The algorithm for calculating the vertical wind is described in details in Wang et al. (2009, Wang, J., J. Bian, W. O. Brown, H. Cole, V. Grubišić, K. Young, 2009: Vertical Air Motion from T-REX Radiosonde and Dropsonde Data. *J. Atmos. Oceanic Technol.*, **26**, 928–942.).

Table 2 - EOL Sounding File Format (dropsonde and radiosonde)

```
Data Type/Direction:                    AVAPS SOUNDING DATA, Channel 3/Descending
File Format/Version:                    EOL Sounding Format/1.1
Project Name/Platform:                  DYNAMO 2011, NOAA P3
Launch Site:
Launch Location (lon,lat,alt):          82 54.92'E 82.915400, 6 15.92'S -6.265300,  6437.40
UTC Launch Time (y,m,d,h,m,s):          2011, 11, 09, 07:45:34
Sonde Id/Sonde Type:                    094355195/
Reference Launch Data Source/Time:      IWGADTS Format (IWG1)/07:45:34
System Operator/Comments:               olney/none, none
Post Processing Comments:               Aspen Version 3.1; Created on 01 Feb 2012 23:12 UTC; Configuration research-dropsonde
TDDryBiasCorrApplied

/
  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 3 - 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
18	Vertical Wind	Meters/Second	Calculated
19	Filtered Vertical Wind	Meters/Second	Calculated

III. Data Quality Control Process

1. Profiles of pressure, temperature, RH, wind speed and descent rate from the raw D-files are first examined to determine if all of the files contain data, and to ensure that nothing looks suspicious. Doing this allows us to determine if a sounding was started up, but not launched, or if the data contains any features that warrant further investigation.

2. The raw soundings files are then processed through the Atmospheric Sounding Processing ENvironment (ASPEN) software, which analyzes the data, performs data quality control and smoothing, sensor time response corrections, and removes suspect data points.

3. Time series plots of quality controlled temperature, RH, wind speed, and fall rate, are used to examine the consistency of soundings launched during each flight, and to show the variability of soundings from different missions. These plots are also used to determine if the sounding did not transmit data to the surface, or if there was a "fast fall" caused by failure of the parachute to properly deploy.

4. Profiles of temperature, RH and winds from the quality controlled soundings are visually evaluated for outliers, or any other obvious issues.

5. A dry bias in the relative humidity measurements was discovered, in the Spring of 2016, in all RD94 dropsondes from 2010 to present and all mini-dropsondes (NRD94) collected. This dry bias is strongly temperature dependent and most significant at cold temperatures. It is considered small at warm temperatures. All sounding files undergoing post-processing have been corrected for this error and contain the flag, 'TDDryBiasCorrApplied', in the last line of the header to confirm that this correction has been applied. For more information on the dry bias, please access the technical note, linked below, which contains information on the origin, magnitude and impact of the dry bias.

   NCAR/EOL Technical Note: Dropsonde Dry Bias

   https://www.eol.ucar.edu/system/files/software/Aspen/Windows/W7/documents/Tech%20Note%20Dropsonde_Dry_Bias_20160527_v1.3.pdf

6. Finally, histograms of pressure, temperature, relative humidity, wind speed and wind direction are created to examine the distribution, range, and characteristics of each parameter.

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 (Tables 4 & 5):

1. One sounding file was removed from the final archive because it contained no useful atmospheric data. According to operator notes, the telemetry of the sonde failed just after launch.

2. **Data not to the surface:** Three quality controlled dropsonde files have missing data near the surface. One sonde (D20111208_103147) experienced a loss of signal and failed to transmit useful data to the surface. One file (D20111208_084114) contained considerable noise near surface which was discarded during QC, and another (D20111116_120334) had premature loss of the temperature sensor at approximately 900 hPa (Figure 2). As a result, geopotential altitude in these soundings was calculated from the flight level downward.

3. **Fast Fall/Partial fast fall:** There were three dropsondes where the parachute did not deploy or did not deploy properly, two sondes were fast falls and one sonde was a partial fast fall (Figure 3). Failure of the parachute to properly deploy results in dropsondes falling at an accelerated rate (and often tumbling) causing winds to be unreliable. For these soundings, wind speed, wind direction, U/V winds, and vertical winds are set to missing where the fall rate is accelerated.

4. **No GPS data:** There was one sounding with no GPS data. Therefore, it contains no wind or position (lat, lon and GPS height) data in the final QCed files.

5. **Errors with Accurate Launch Detection:** Eighteen dropsondes experienced problems with the launch detect mechanism. In these cases the launch detect was either triggered early or it failed completed. No data is lost when this occurs, however raw data is incorrectly recorded as "pre-launch", for failed launch detect, or it is incorrectly flagged as "in-flight", for early launch detect. Additionally, the filenames and launch times and flight level data recorded are incorrect. All data were recovered and correct launch times were assigned.

Table 4 - Summary Statistics

Description	# of Files	Filenames	Comments/Corrections
Total	470 dropsondes deployed 469 in final archive (**99.8% success rate**)	D20111130_063929	One file contained no useful data and was deleted
Complete Profiles	462 (98.5%)		Seven soundings excluded from total 469 are the following ones listed below.
No GPS	1	D20111213_061239	No corrections applied. Wind and GPS Alt data are missing.
Fast Fall	2	D20111124_02551 D20111208_080332	All wind data are set to missing.
Partial Fast Fall	1	D20111113_060405	Parachute opened late. Wind data where fast fall occurred are set to missing.
Data Not to Surface	3	D20111116_120334 D20111208_084114 D20111208_103147	Geopotential altitudes were computed from flight level downward.

Table 5 The list of files with early or no launch detects.

Description	# of Files	New Filename (UTC lau time hhmmss)	Original Filename (UTC lau time hhmmss)	Comments/Corrections
Early Launch Detect	16	D20111111_**092308** D20111111_**095902** D20111116_**082313** D20111122_**031722** D20111122_**032142** D20111122_**032505** D20111122_**070817** D20111124_**074256** D20111128_**030516** D20111208_**044413** D20111208_**045108** D20111208_**052609** D20111208_**081535** D20111208_**104826** D20111208_**105507** D20111213_**060924**	D20111111_**091359** D20111111_**095857** D20111116_**082200** D20111122_**031717** D20111122_**032137** D20111122_**032419** D20111122_**070015** D20111124_**074157** D20111128_**030157** D20111208_**044049** D20111208_**044923** D20111208_**052412** D20111208_**081249** D20111208_**104824** D20111208_**105506** D20111213_**060729**	All data was recovered and correct launch times were assigned to each file
No Launch Detect	2	D20111119_**115223** D20111126_**040434**	D20111119_**114808** D20111126_**040230**	All data was recovered and correct launch times were assigned to each file

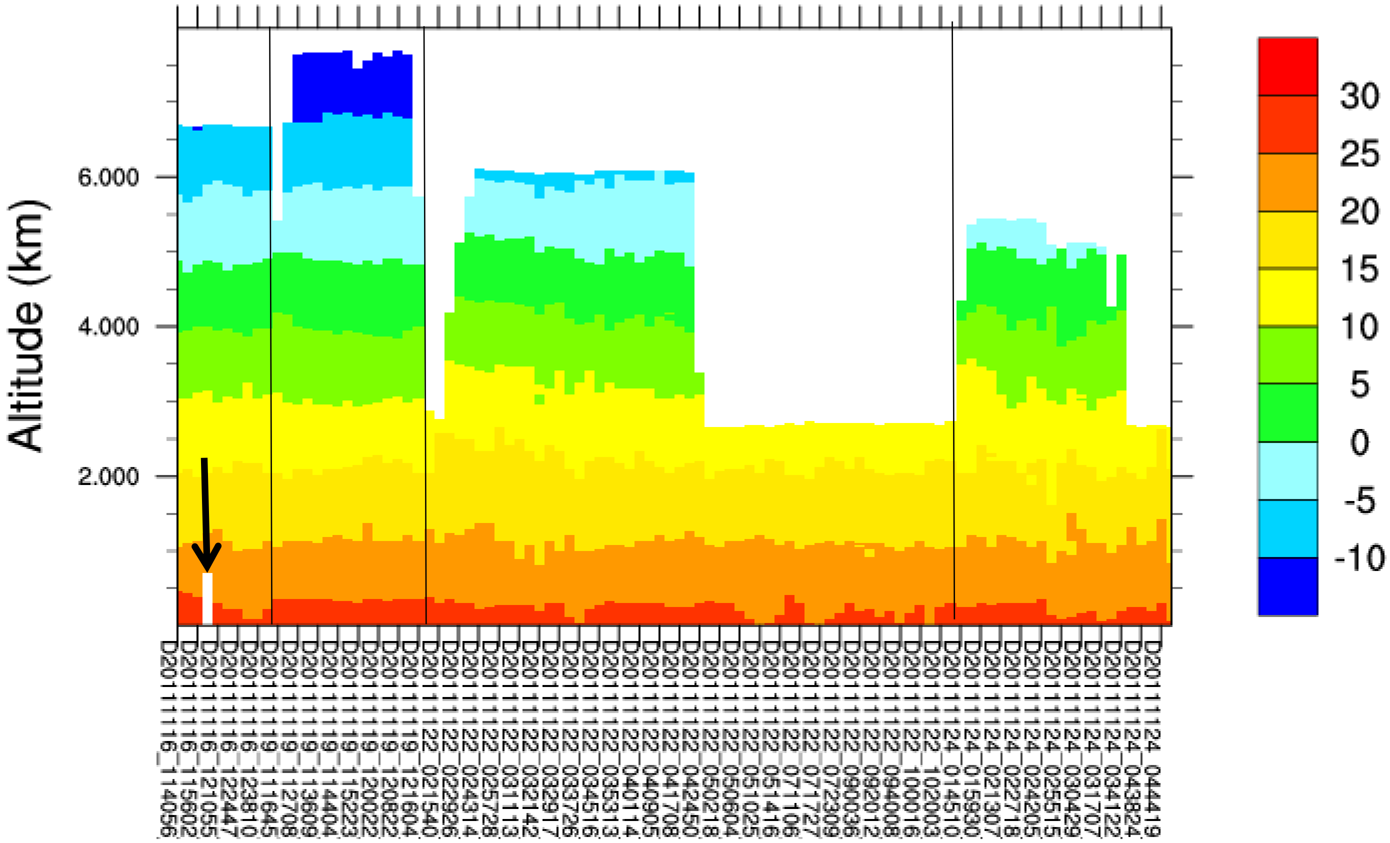

Figure 2- Temperature (°C) profiles of final QCed data for the first 100 soundings. The arrow indicates one sounding that contains missing data near surface.

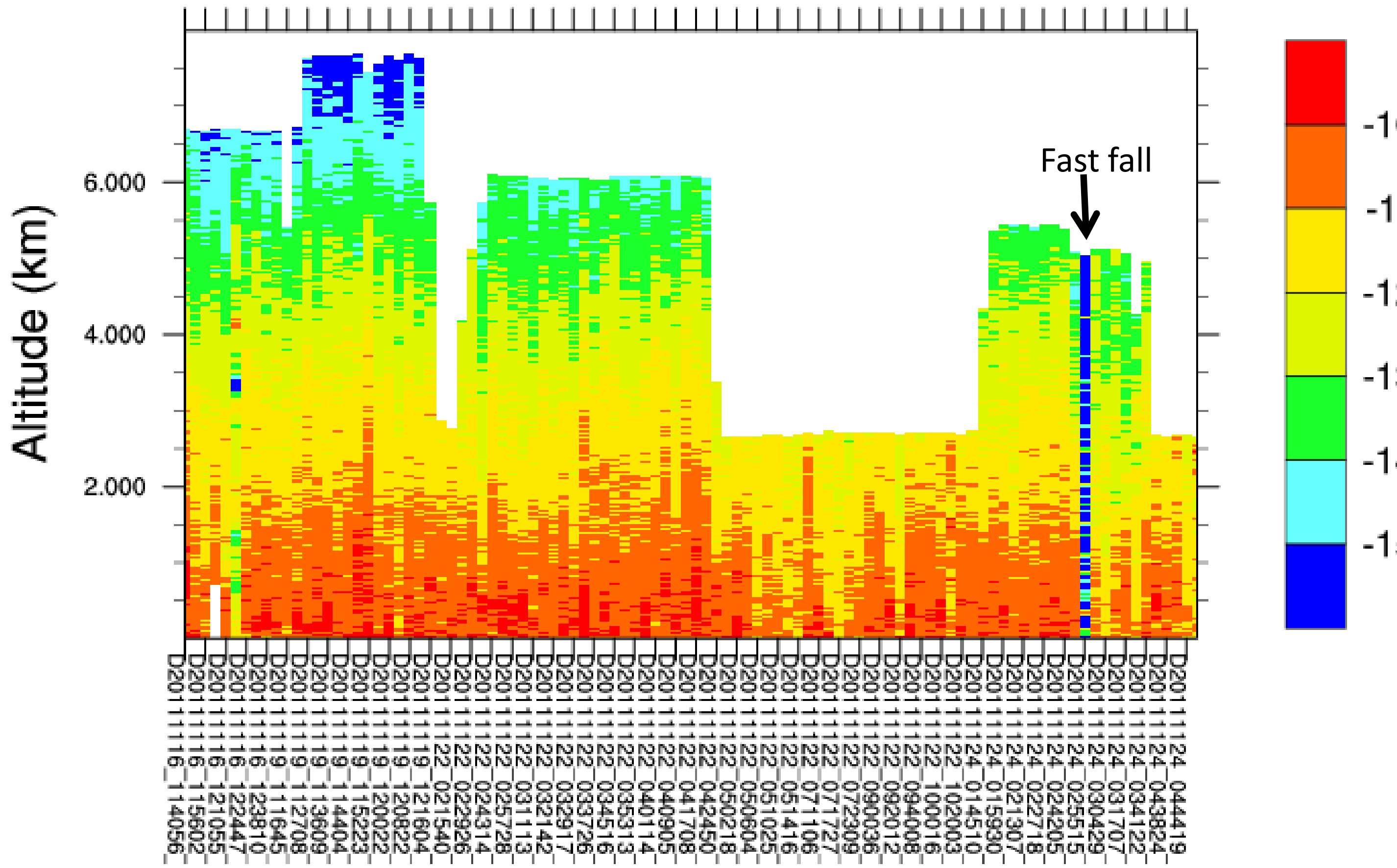

Figure 3 - Pressure-calculated fall rate (m/s) profiles of final QCed data for first 100 sounding. One slightly accelerated sounding and one fast fall sounding are indicated by the arrows.