NCAR GPS Dropsonde Humidity Dry Bias

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1 Executive Summary

A dry bias in the RD94, mini dropsonde (NRD94) and Driftsonde MIST sonde humidity measurements has been discovered, which has existed since 2008. This document describes the background of the dry bias, how to identify impacted files, how to correct existing data, and how to implement a correction in AVAPS®.

The Atmospheric Sounding Processing Environment (ASPEN) starting with version 3.3-236 is used to correct this dry bias both in reprocessing of existing raw data (i.e. D-files) as well as in real-time data acquisition.
The correction has also been implemented into the AVAPS data acquisition software starting with version 3.9.5. This version must only be used, if ASPEN version 3.3-236 or later is used at the same time to make sure that the correction is properly documented. Double correction will not occur when using both updated programs (AVAPS 3.9.5 and ASPEN 3.3-236).
Users must upgrade ASPEN to version 3.3-236 or higher and should upgrade AVAPS to version 3.9.5 or higher.
Existing files in the D-, EOL-, and FRD format can be corrected using the python script *aspenfixrh* in the linux environment.

2 Background

2.1 Origin of the dry bias

The NCAR GPS dropsonde has been using a modified sensor module of the Vaisala RS90 and later of the RS92 radiosonde since its inception in the mid-1990s. In 2009 a major upgrade of the aircraft dropsonde took place including replacing the original Vaisala Pressure, Temperature and Humidity (PTU) module with a next generation RS92 PTU module. As part of this development PTU calculations were moved from the AVAPS software package in the aircraft data system to a Vaisala provided microprocessor in the dropsonde. A bug in the microprocessor firmware led to a systematic temperature dependent dry bias in the RH sensor. The new dropsonde design product code was changed from RD93 to RD94. The Driftsonde MIST sonde and the smaller Mini-Dropsonde (current product code NRD94) use the same technology as the RD94 and have the same dry bias issue. The NRD94 is being used with the automated launch systems onboard the NCAR G-V and the NASA Global Hawk.

2.2 Magnitude of the dry bias

This dry bias is strongly temperature dependent. It is considered small at warm temperatures and becomes strong at cold temperatures. The approximate magnitude of the dry bias as a function of temperature is shown in Figure 1 as factor of the correct value.

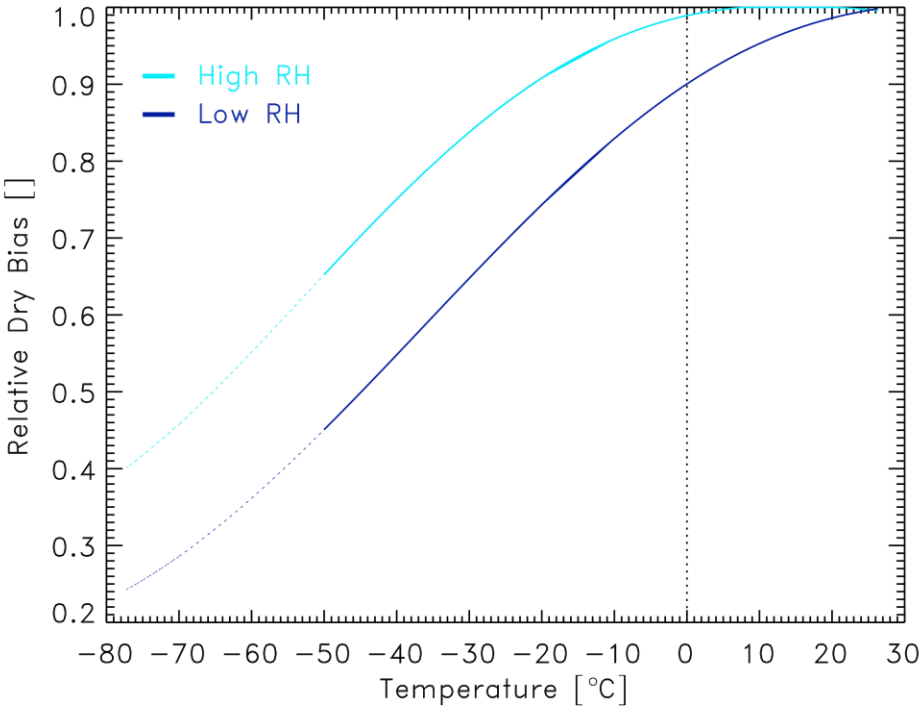

Figure 1: Approximate relative dry bias for high and low humidity conditions as factor of the correct relative humidity reading.

For dry conditions and at a cold temperature of -50°C the relative dry bias may be as large as 50%. For wet conditions the relative dry bias may be as large as 30% and negligible at temperatures warmer than 0°C. Due to the fast falling speed of dropsondes and a relatively slow equilibration time of the humidity sensor, relative humidity measurements from dropsondes currently are difficult to achieve below temperatures of approximately -50°C. The change to dashed lines in Figure 1 indicates that other factors limit the usefulness of humidity data at cold temperatures. An example of the dry bias as function of altitude is shown in Figure 2 with data of a high altitude drop from an altitude of 17 km. In this profile the corrected profile shows significant supersaturation over ice, indicating the possibility for the existence of cirrus clouds. The dry biased profile does not show the possibility for the existence of cirrus clouds.

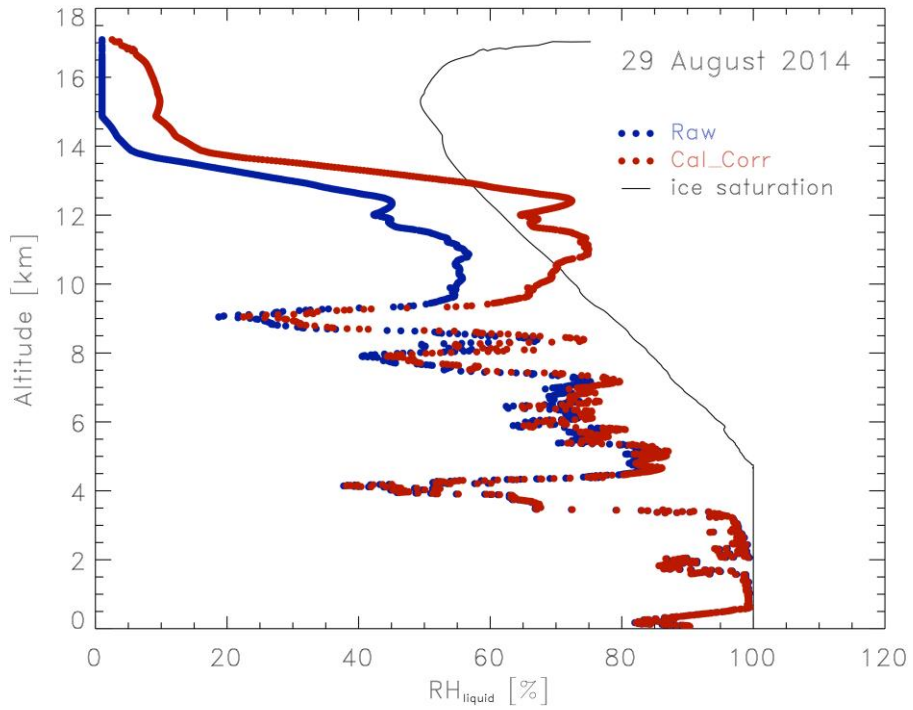

Figure 2: Example of the dry bias as function of altitude. The blue data points show the original dry biased data, the red data points show the corrected data. The black line indicates the ice saturation for reference.

Most of the atmospheric water vapor is contained in the lower (and warmer) troposphere. Thus, the impact of the dry bias on total precipitable water vapor is significantly less. The overwhelming number of dropsondes is launched in mid and low latitudes, where the dry bias in total precipitable water vapor is 1% or less.

2.3 Impacted sonde models and data files

The dry bias impacts all observations of the RD94, which was introduced in late 2009, all NRD94 (mini dropsonde) observations since its inception in 2010 and all observations of the Driftsonde MIST sonde used during T-PARC in 2008 and Concordiasi 2010.

2.3.1 Impacted raw data files

Impacted AVAPS raw data D-files can be identified by scanning the metadata in the footer of the data files for the sensor module code. Impacted sounding data will have a sensor identifier of either:

- RSS904
- RS904
- RSS921

2.3.2 Impacted product data files

Product data files may be of the *.EOL, *.FRD, *.CLS, *.CSV format type or may be in the form of TEMPDRPOP (FM 37) messages. These product data files cannot be uniquely identified due to the limitations in the data formats. Some guidelines are provided here to identify impacted soundings:

- No aircraft observations prior to 2010 are impacted, except for a small number of NOAA test drops and the November/December PLOWS observations.
- Starting in 2010 product data files may be of either type and cannot be identified using metadata of the product file. The user will need to refer to the metadata entry of the AVAPS raw data D-files or A-files and identify the impacted sensor from section 2.3.1.
- All product data files for campaigns using the NRD94 (Mini dropsonde) are impacted.
- All data files of the Driftsonde field programs T-PARC and Concordiasi using the MIST sondes are impacted.

2.3.3 Corrected raw data files

Starting with AVAPS data acquisition software version 3.9.5, raw data D-files already contain corrected humidity data. The presence of the correction in D files can be identified by the keyword '`TDDryBiasCorrApplied`' in the '`COM Operator Name/Comments`' comment line. These files can be processed by the Atmospheric Sounding Processing Environment (ASPEN) starting with version 3.3-236. ASPEN will scan for this keyword and not apply the dry bias correction a second time. ASPEN version 3.3-236 and later will also output this keyword into the product data files to track that the data have been properly corrected.

Older versions of ASPEN must not be used with already corrected raw data D-files, since they do not properly track the keyword indicating the correction to the RH dry bias.

3 Correction of the dropsonde RH dry bias

An algorithm to correct this dry bias has been provided by Vaisala and was implemented as additional correction step, which the ASPEN applies to raw data AVAPS D-files containing the dry bias or the AVAPS data acquisition software (ver 3.9.5) implements. Users are reminded to never use AVAPS raw data files (D-files) for scientific studies of operational use in forecasting. Only ASPEN output files should be used for any quantitative analysis of dropsonde observations.

3.1 Existing data files

ASPEN implemented this dry bias correction starting with version 3.3-236 and generates product files, which are free of this dry bias. All subsequent versions maintain the capability to correct this dry bias.

The application of the dry bias correction is indicated by:

- The string 'TDDryBiasCorrApplied' is added at the end of the Comment data line *.EOL, *.FRD, and *.CLS data files
- A new key 'TDDryBiasCorrApplied' has been added to the *.csv and *.nc data files with a value of 'applied'.
- TEMPDROP messages do not provide any possibility to indicate the dry bias correction. This data format will need to be used with caution.
- BUFR data files have not been used prior to the discovery of this issue. Therefore, all BUFR data files, which will be generated in the future, have the dry bias correction applied.

Data files in the D-, EOL-, and FRD-format can independently be corrected by using the python script *aspenfixrh*. This script will generate a file of the same format with the dry bias corrected. This script is based on ASPEN and checks for the presence of the key 'TDDryBiasCorrApplied'. Double correction of files is not possible for any of the files.

3.2 Real-time data recording

To correct the dry bias in real-time data, ASPEN versions running on the AVAPS computer must be updated to at least version 3.3-236. This version will assure that raw data AVAPS D-files will be properly processed to generate real-time quality controlled ASCII EOL files, TEMPDROP message, as well as Skew-T plots.
If ASPEN is used on other computers to generate product files and skew-T plots, then ASPEN must be updated on these computers.
The correction was built into the default processing mode, so no modification needs to be done to the ASPEN configuration in order for it to apply the correction to raw files in real-time. ASPEN identifies impacted data files and will correct only data files, which are impacted by the dry bias.

Starting with AVAPS data acquisition software version 3.9.5, the correction will already be applied and raw D-files will not have the dry bias. The output of this AVAPS data acquisition software version no longer requires a post correction by ASPEN or the use of *aspenfixrh.* The AVAPS data acquisition software adds a metadata keyword in the raw data files, indicating that the dry bias has been corrected. However, it is imperative that ASPEN version 3.3-236 or later is used in the processing of AVAPS raw data to properly track the metadata keyword indicating that the correction has been applied through to the final output files as described in section 3.1. A double correction of the dry bias will not happen if both updated software versions are used.

4 Resources

ASPEN and aspenfixrh can be downloaded at: https://www.eol.ucar.edu/software/aspen

Please be sure to download Aspen version 3.3-236 or higher.