

## J32.5 DEVELOPMENT OF A DISPLAY TOOL TO QUALITY CONTROL WEATHER BALLOON DATA FOR SPACE LAUNCH VEHICLES

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### 1. INTRODUCTION

Continuous atmospheric data analysis is an important factor for space launch vehicle design and operations. The balloon quality control tool was developed by NASA's Marshall Space Flight Center (MSFC) Natural Environments Branch (NEB) for monitoring quality control processes and verifying the automated flags created on the balloon data sets analyzed. The data sets currently analyzed are comprised of high-resolution and low-resolution balloon data from NASA Kennedy Space Center (KSC), co-located on the United States Air Force's Eastern range (ER) at the Cape Canaveral Air Force Station. The NEB was tasked to perform a quality assessment of these data sets and needed a tool to confirm the quality control (QC) flags produced from an automated process and add additional QC flags if necessary. This Graphical User Interface (GUI) was developed to visualize all of the data from these balloon sets, display any flags from the automated QC process, and add additional flags to variables if necessary. The GUI was developed in Python 3.6 utilizing different packages available such as pandas for data analysis and manipulation, NumPy for high-performance multidimensional array and tools to compute with and manipulate arrays, Matplotlib for plotting data and Tkinter to build the GUI.

### 2. BACKGROUND

The automated QC process was developed for a database of meteorological data from KSC and the ER. This database includes wind towers, balloons, the 915 MHz Doppler Radar Wind Profilers, and Tropospheric Doppler Radar Wind Profiler (TDRWP) data. For this document's purpose, only the balloon QC process will be explained.

This section provides a summation of the automated checks, which Brenton (2018) describe thoroughly. These checks address data that apply to both Low Resolution Flight Elements (LRFE) and High Resolution Flight Elements (HRFE), both in

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conjunction and separately. The first check that applies to both systems examines whether any gaps exist in the profile, determines if at least half of the profile is available, and flags any gaps larger than 16,400 feet. Both types of balloons also have a check to confirm that the altitudes are in ascending order. Lastly, there is a wind speed duo-check that will flag data with wind speeds of zero knots above the surface. Realistic data threshold checks and checks for values that exceed six standard deviations from the annual mean for each system's unique variables apply to unique variables of both systems. LRFE data has additional QC checks to be applied. One check flags temperature values that exceed a lapse rate of 8°F per 100 feet. The final balloon data check applied identifies data points from LRFE that provide pressure, temperature, altitude and dew point, excluding density which is to be calculated at a later time during archiving. (Brenton, 2018)

These checks are performed over the data sets in question before analysis begins. This portion of preprocessing includes utilizing Shutil and Itertools to save time manipulating directory trees, keeping permissions, content and names, as well as, producing different sequences. The way the data is visualized and QC flags are confirmed were developed in the GUI.

### 3. SOFTWARE DEVELOPMENT

This GUI was developed to be a tool that one can operate any operating system (OS) with minimum set up effort by the end user. Anaconda 5.1, which has already been accepted for previous projects WAND (Orcutt, 2018) and PrESTo (Orcutt, 2017), was selected for consistency. It runs Python 3.6 and includes many other useful packages including Pandas, NumPy, Matplotlib and Tkinter, which were all used to build the GUI.

### 4. SOFTWARE DESIGN

Figure 1 displays the window for the GUI at initialization. This window has directory selection

under “File”, “Save Progress” for the current data set that is being worked on, and “Close” to close the GUI which can also be achieved with the “X” in the right upper corner.



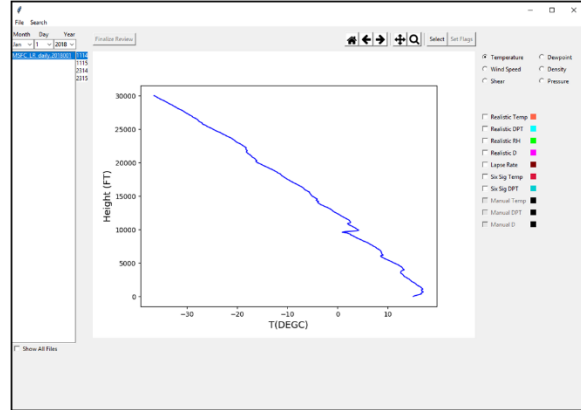
**Figure 1:** Example of the GUI window when first initialized.

Once a working directory has been selected, the left frame will populate with selectable balloon profiles (Figure 2). To the right of “File”, is the “Search” menu option. Here two visible options are given: “Text Search” and “Date Search”. Once either of these have been selected the third option of “Close Search” initializes for selection. “Text Search”, creates a search bar in which the user can type and the list of files available below updates accordingly.



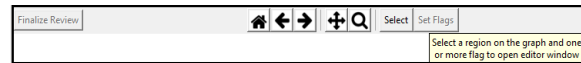
**Figure 2:** Example of “Text Search”

“Date Search”, (Figure 3), creates three drop downs which are clickable and display Month, Day, and Year, also populating the selectable files to match.



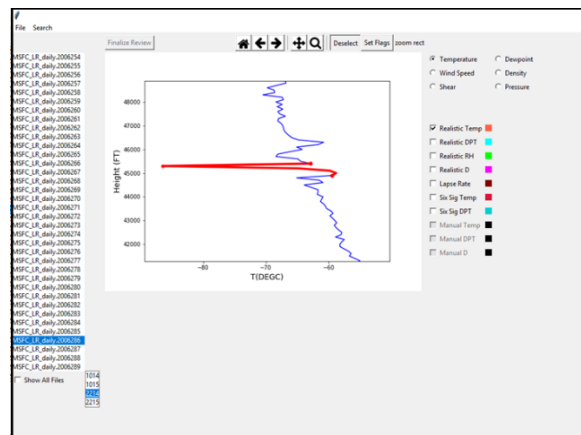
**Figure 3:** Example of “Date Search”

Mousing over each that is available above the plotting area will give the user a description for each button (Figure 4). “Home” Resets the view to the original view. If the user has manipulated the view with zooms or panning, this button will bring the view back to the original plot.



**Figure 4:**

While manipulating the view of the plot, the “back” arrow and “forward” arrows change the view to the previous and next view respectively. Next, the “pan” button will pan the axis with a left mouse click and zooms with a right mouse click. The “magnify” button allows the user to zoom over an area with a rectangle only. The “Select” function initializes the QC phase of the GUI (Figure 5). Once this option is selected, the GUI waits for the user to select two points along the profile that define a range of heights to examine for the given variable.



**Figure 5:** Example of selecting two data points surrounding a concerning area

Once the area of concern is selected, the appropriate flag is selected from the list provided to the right of the plot. In the example presented in Figure 5, one would examine the realistic temperature flag. Next, the “Set Flags” button is pressed to add these flags to the data file.

- Manual shear
- Manual pressure
- Manual density

The flag that has been tripped in Figures 5 and 6 is an automated realistic temperature flag. When the window opens, it is already flagged as a “1” and is highlighted in the color coordinating to that variable. Selecting “1” in the drop down menu confirms that the flag corresponding to the data point of concern is correct. This process is repeated for all suspect and/or previously-flagged data points in the profile.

ALT(FT)	AutoQC	T(DEGC)	QCManualTemp
44900	00001100100000100	-59.5	0
45000	00001100100000100	-58.8	0
45100	00001100100000100	-59.8	0
45200	00001100100000100	-64.8	0
45300	00011100100100100	-86.5	0
45400	00001100100100100	-62.9	0

Figure 6: Example of data editor

Next, the data editor appears. Here the flags in the data are set as a “1” or “0”, with “1” meaning the data point has failed the given QC check. The binary QC flags are attributed to the following checks:

- Excessive data gaps
- Uneven altitude increments
- Zero wind speed
- Realistic temperature
- Realistic dew point
- Realistic relative humidity
- Realistic wind direction
- Realistic wind speed
- Realistic shear
- Realistic pressure
- Realistic density
- Excessive lapse rate
- Calculated density
- Six sigma temperature exceedance
- Six sigma dew point exceedance
- Six sigma wind speed exceedance
- Six sigma shear exceedance
- Flag that denotes that all data has been viewed
- Manual temperature
- Manual dew point
- Manual wind speed

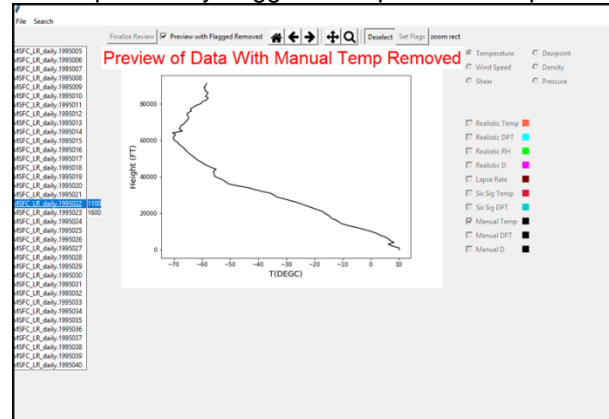


Figure 7: Example of previewing data with flagged points removed.

Once the manual checks have been confirmed for any data that was either automatically flagged or manually flagged, selecting the “Manual variable check” associated with the variable that was flagged will prompt the “Preview with Flagged Removed” checkbox (Figure 7). Checking this box removes all flagged data points from the plot providing the user with what the final image of the profile would look like if these points were removed. It is important to note that even though a flag has been set for the data for a variable, that data point will not be removed from the data. The purpose of this QC process, confirmation, and human interaction with the data was not to remove or manipulate data, instead it is to keep the integrity of the data while also allowing any future users of the data to be alerted of these pre-processed

To finalize and save all manual observations and QC checks of the data, every variable must be analyzed by the user. The button “Finalize Review”. (see Figure 1), will not populate as selectable until this has been done. Furthermore, hovering the mouse over this button will tell the user exactly which variables still need to be viewed.

## 5. FUTURE WORK

The NEB is consistently receiving requests from the aerospace meteorology community for data sets of different atmospheric parameters including complete balloon data sets. Currently, the NEB uses numerous different sets that contain either differing periods of record, altitude coverage, and/or data sources that have been completed in the past for different analyses. The goal is to have a single master data set comprised of all original data with these QC flags allowing the user to remove the flags if they feel it is necessary for their work or retaining the data points that have been flagged in for their needs. The GUI would be a valuable tool in the development of a master balloon database for use by the aerospace meteorology community.

## 6. ACKNOWLEDGEMENTS

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