TCI_VV.R Manual

Version 1.0

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INTRODUCTION

The Office of Naval Research (ONR) funded Tropical Cyclone Intensity (TCI) experiment launched 725 eXpendable Digital Dropsondes (XDDs) manufactured by Yankee Environmental Systems into three tropical cyclones (TCs): Marty (27–28 September), Joaquin (02–05 October), and Patricia (20–23 October) (Doyle et al. 2017). The strength and locations of updrafts and downdrafts in the three TCs were analyzed in Nelson et al. (2017). The XDD_VV.R software was used and developed for the Nelson et al. (2017) study to calculate the strength of vertical velocity from the Global Positioning System (GPS) fall speeds of sondes. In XDD_VV.R, vertical velocity is obtained for individual data points on each observation day. The data is then combined for each TC and in total to evaluate the radial, azimuthal, and altitudinal frequencies of fata in contoured frequency by radial (CFRD), contoured frequency by azimuthal (CFAzD), and contoured frequency by altitudinal (CFAD) diagrams. The contoured frequency data are computed for data for all radii, within the core (i.e., within three times the radius of maximum wind; RMW), and outside of the core (i.e., outside of three times the RMW). The results from the CFAzD diagrams are statistically verified and supported by creating notched boxplots of median bootstrapped samples from each shear quadrant: downshear-right (DR), downshear-left (DL), upshear-left (UL), and upshear-right (UR). The TC centers are computed using a zero-wind-center (ZWC; Willoughby and Chemlow 1982, Creasey and Elsberry 2017). The RMW is obtained from both a sonde-derived RMW and a Hurricane Imaging Radiometer (HIRAD; Cecil et al. 2016) RMW. For more information about the methodology, readers are encouraged to read Nelson et al. (2017) and to peruse the R files within the XDD_VV.R code.

This code uses data obtained during TCI, all use of this code and TCI data MUST be properly cited.

INSTALLATION INSTRUCTIONS

The following instruction manual assumes that you have working and up-to-date versions of R and RStudio. Majority of the code in the TCI_VV software package is R source code. For more information about R and instructions to download R for free, please see: https://www.r-project.org. For more information about RStudio and instructions to download RStudio for free, please see: https://www.rstudio.com/products/rstudio/download/.

Computing requirements:

1. Software, data, and output alone requires 2 GB space
2. R (verified on version 3.4.0)
3. RStudio (verified on version 1.0.143)

Other requirements:

1. pracma R package
2. plotrix R library
3. matrixStats R library
4. plot3D R library
5. akima R package

1. Download the XDD_VV.tar.gz file from: http://www.atmos.albany.edu/student/tn354126/XDD_VV_Code/
   a. The file will be approximately 300 MB
2. Move XDD_VV.tar.gz into whatever directory that you want to run the software
3. Untar the XDD_VV.tar.gz file by typing into the command line:
   a. tar –xzf XDD_VV.tar.gz
4. Verify that the required R packages or libraries listed above in Other requirements are installed
   a. To install any missing package or library, launch RStudio or the R shell (at the command line) and type: install.packages("INSERT_PACKAGE_NAME_HERE") into the terminal prompt/Console
      i. Example: install.packages("akima")
5. Install the XDD.VV.2017.1 library
   a. At the terminal window, type: cd …/XDD_VV/Lib

   b. **NOTE: ".../" means directory path where you have untarred/unzipped the software!!!!**
   c. Type: R CMD INSTALL XDD.VV.2017.1_1.0.tar.gz

6. Test that the XDD.VV.2017.1 library has installed correctly
   a. At the RStudio Console, type: library(XDD.VV.2017.1)
   b. The output should resemble:

```
Attaching package: 'XDD.VV.2017.1'

The following object is masked from 'package:graphics':

  filled.contour
```

SCRIPT FILE DESCRIPTIONS

1. **Constants.R:** Contains required constants and variables
2. **Joquin_box_1.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, after a differential pressure fall speed screening of 1 m s^{-1} is applied
3. **Joaquin_box_5.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, after a differential pressure fall speed screening of 5 m s^{-1} is applied
4. **Joaquin_box_accel.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, uses the differential pressure fall speed rather than GPS fall speed
5. **Joaquin_box.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, no differential pressure fall speed screening is applied
6. **Marty_box_1.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, after a differential pressure fall speed screening of 1 m s^{-1} is applied
7. **Marty_box_5.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, after a differential pressure fall speed screening of 5 m s^{-1} is applied
8. **Marty_box_accel.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, uses the differential pressure fall speed rather than GPS fall speed
9. **Marty_box.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, no differential pressure fall speed screening is applied
10. **Patricia_box_1.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, after a differential pressure fall speed screening of 1 m s^{-1} is applied
11. **Patricia_box_5.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, after a differential pressure fall speed screening of 5 m s^{-1} is applied
12. **Patricia_box_accel.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, uses the differential pressure fall speed rather than GPS fall speed

13. **Patricia_box.R:** Plotting script to create notched boxplots of median bootstrapped vertical velocity within a given radial section, no differential pressure fall speed screening is applied
14. **XDD_VV_Date_Arrays.R:** Script containing a long list of arrays used in the XDD_VV_Date.R script
15. **XDD_VV_Date.R:** Script used to extract sounding data from sondes launched on any given day and calculate vertical velocity.
16. **XDD_VV_Merged_Plots.R:** Plotting script to create contoured frequency diagrams and notched boxplots for the total dataset
17. **XDD_VV_Merged.R:** Script used to extract all vertical velocity data to compute statistics
18. **XDD_VV_Options.R:** User modification file to change the date, storm, and all flags
19. **XDD_VV_SFC_FALL.R:** Script that examines the last data point altitude, density, fall speed, and sonde parameter for all sondes launched outside of convection.
20. **XDD_VV_Storm_Plots.R:** Plotting script to create contoured frequency diagrams for a single TC
21. **XDD_VV_Storm.R:** Script used to extract vertical velocity data from a single TC to compute statistics
22. **XDD_VV_Thresh.R:** Script used to compute the moderate, strong, and extreme thresholds for updrafts and downdrafts for all four differential pressure fall speed screening methodologies.

DATA FLOW

For running extraction code for any given date, the data flow is shown in Figure 1a. Data from the Level 1 output of SQZ (Harrison 2017) has been extracted once per second during any given sounding into a ".int" file saved in "…/STORM_FILE/YYYYMMDD/zz_merged/Level1_outputs/int_2". For example, data from 27 September 2015 in Marty is saved in "…/Marty_and_Joaquin/20150927/zz_merged/Level1_outputs/int_2/". Soundings that terminated at altitudes above 500 m have been removed and placed into a subdirectory called "Too_high/" or "Sondes_too_high/". The Master_control.R script calls the XDD_VV_Options.R script, reads flags and information set by the user, and sources the XDD_VV_Date.R code. The XDD_VV_Date.R code sources Constants.R, XDD_VV_Date_Arrays.R, and XDD_VV_SFC_FALL.R. XDD_VV_Date.R then pulls in data from the National Hurricane Center Best Track data and shear and motion from SHIPS. Sounding data from the ".int" files is extracted. Vertical velocity is computed for all data points and the ZWC is found. The best-fit RMW between the HIRAD RMW and the XDD-derived RMW to the NHC Best Track data set is used. Data is output into .txt files in the subdirectories of the "…/XDD_VV/Output/" directory.

For running extraction code for any given TC, the data flow is shown in Figure 1b. The Master_control.R script calls the XDD_VV_Options.R script, reads flags and information set by the user, and sources the XDD_VV_Storm.R and/or the XDD_VV_Storm_Plots.R code along with the "box" codes (e.g. Patricia_box_1.R). The XDD_VV_Storm.R code sources Constants.R, then pulls in data from the National Hurricane Center Best Track data and shear and motion from SHIPS. Data output from XDD_VV_Date.R is imported into the script and statistics of convection are computed after data removal is completed.

For running extraction code for the merged, total dataset, the data flow is shown in Figure 1c. The Master_control.R script calls the XDD_VV_Options.R script, reads flags and information set by the user, and sources the XDD_VV_Merged.R and/or the XDD_VV_Merged_Plots.R code along with the "box" codes (e.g. Total_box_1.R). The XDD_VV_Merged.R code sources Constants.R, then pulls in data from the

National Hurricane Center Best Track data and shear and motion from SHIPS. Data output from XDD_VV_Date.R is imported into the script and statistics of convection are computed after data removal is completed.

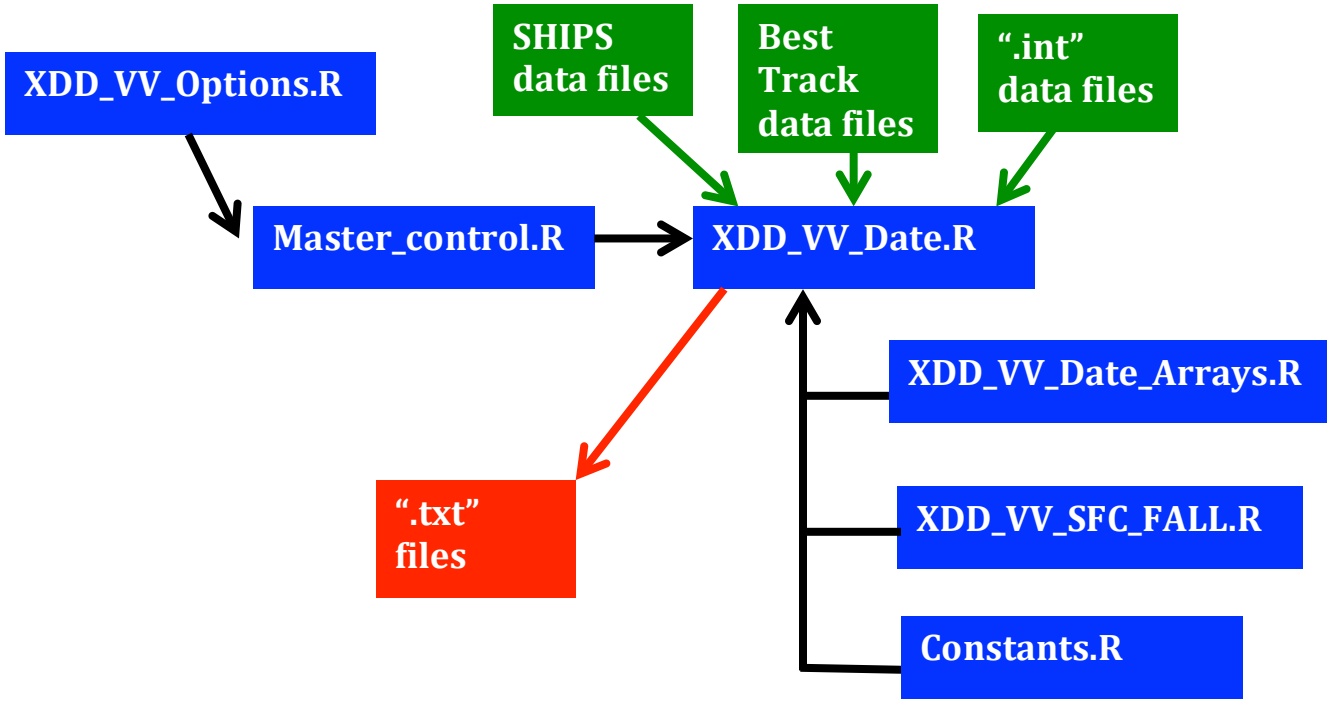

Figure 1a. Data flow for extracting data and calculating vertical velocity for any given date during TCI.

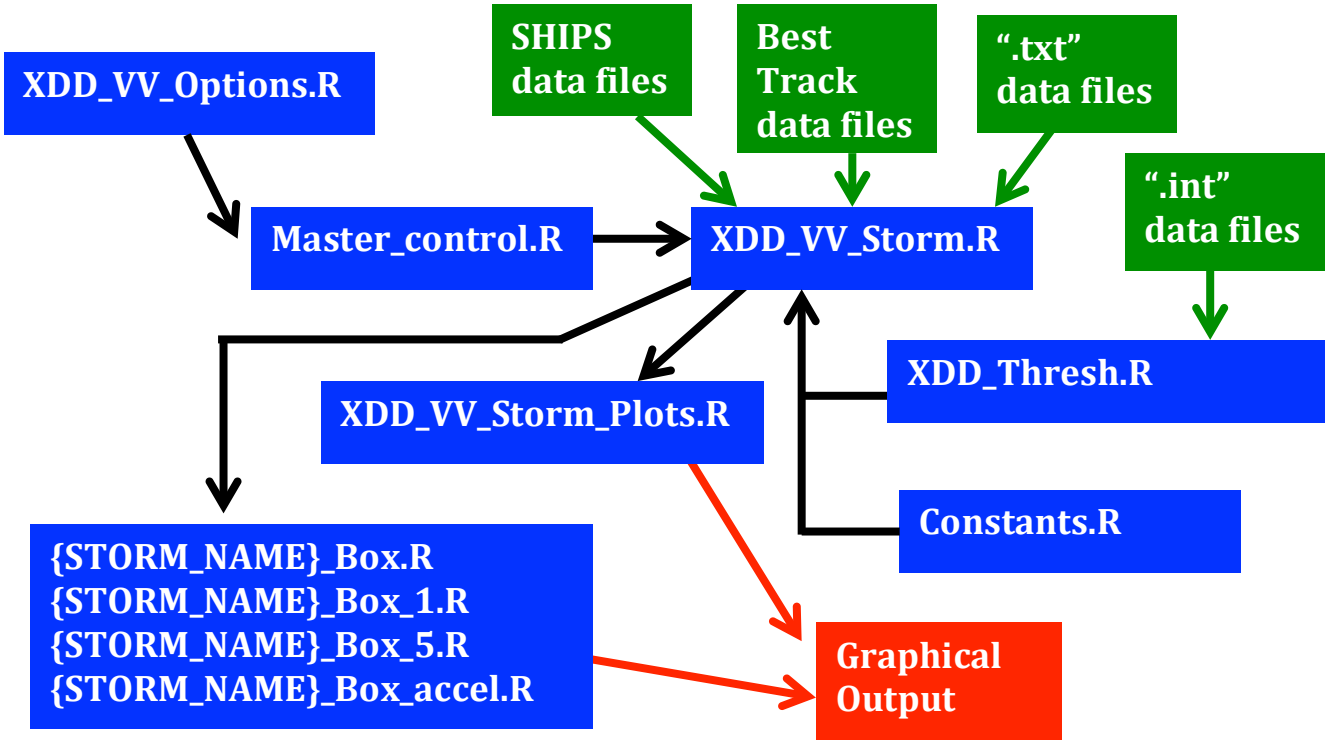

Figure 1b. Data flow for creating contoured frequency diagrams and statistical analysis of vertical velocity for any given TC during TCI.

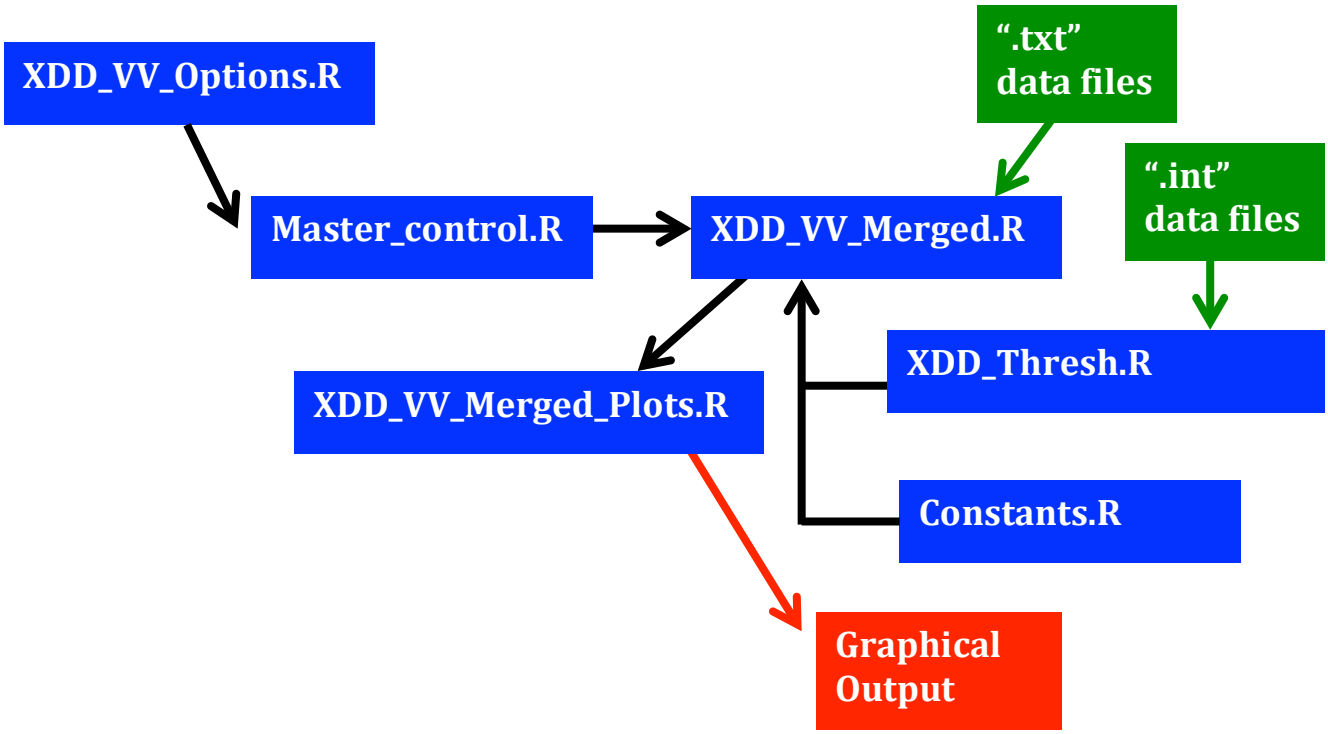

Figure 1c. Data flow for creating contoured frequency diagrams and statistical analysis of vertical velocity for all data in Marty, Joaquin, and Patricia during TCI.

RUNNING INSTRUCTIONS

1. cd into the …/ XDD_VV/ directory
2. Change the "root" directory in the Master_control.R and XDD_VV_SFC_FALL.R files to be your "…/" directory, where you unzipped/untarred the XDD_VV.tar.gz file.

To run extraction code for an individual date

1. Open the XDD_VV_Options.R file
2. Change the Enter_storm_name array to be the name of the TC you want to extract data for
    a. Choose either: "Marty", "Joaquin", or "Patricia"
3. Change the Enter_file array to be the directory where the storm data is stored
    a. Choose either "Marty_and_Joaquin" or "Patricia"
4. Change the Enter_date variable to be the date of during TCI that you want to extract data for (Format: YYYYMMDD)
5. Change the enter_day_number variable to match the Enter_date variable:
    a. 1 = 20150927
    b. 2 = 20150928
    c. 3 = 20151002
    d. 4 = 20151003
    e. 5 = 20151004
    f. 6 = 20151005
    g. 7 = 20151020
    h. 8 = 20151021
    i. 9 = 20151022
    j. 10 = 20151023
6. Turn the Date_flag to 1
    a. To check if all sondes reached an altitude of 500 m, turn rejection_flag to 1
    b. To write ".txt" output files to be saved for each day or imported into another script, turn write_output_flag to 1
7. Keep all other flags at 0
8. Run the Master_control.R script
    a. RStudio: Open Master_control.R, click the source icon

b. R shell (command line): Rscript Master_control.R

To run extraction code for an individual TC

1. Open the XDD_VV_Options.R file
2. Change the Enter_storm_name array to be the name of the TC you want to extract data for
   a. Choose either: "Marty", "Joaquin", or "Patricia"
3. Change the Enter_file array to be the directory where the storm data is stored
   a. Choose either "Marty_and_Joaquin" or "Patricia"
4. Leave the Enter_date and enter_day_number variables alone…their specific values have no bearing on the script!
5. Turn the Storm_flag to 1
   a. To create all of the plots from Nelson et al. (2017), turn the Plot_storm_flag to 1
6. Keep all other flags at 0
7. Run the Master_control.R script
   a. RStudio: Open Master_control.R, click the source icon
   b. R shell (command line): Rscript Master_control.R

To run extraction code for all data in a merged composite

1. Open the XDD_VV_Options.R file
2. Leave the Enter_storm_name, Enter_storm_file, Enter_date, and enter_day_number variables alone…their specific values have no bearing on the script!
3. Turn the Merged_flag to 1
   a. To create all of the plots from Nelson et al. (2017) for the Total dataset, turn the Plot_merged_flag to 1
4. Keep all other flags at 0
5. Run the Master_control.R script
   a. RStudio: Open Master_control.R, click the source icon
   b. R shell (command line): Rscript Master_control.R

DATA FILE OUTPUT

Output from the XDD_VV_Date.R include: text files of altitude (km, YYYYMMDD_alt.txt), shear relative azimuth (degrees, YYYYMMDD_az_sr.txt), azimuth (degrees, YYYYMMDD_az.txt), distance (km, YYYYMMDD_dist.txt), differential pressure indicated fall speed (m s^{-1}, YYYYMMDD_dPdt.txt), GPS last data point fall speed (m s^{-1}, YYYYMMDD_fall.txt), GPS point fall speed (m s^{-1}, YYYYMMDD_FS.txt), latitude (degrees, YYYYMMDD_Lat.txt), longitude (degrees, YYYYMMDD_Lon.txt), last data point altitude (m, YYYYMMDD_min_height.txt), pressure (hPa, YYYYMMDD_Press.txt), relative humidity (percent, YYYYMMDD_RH.txt), R* at the last data point (unitless, YYYYMMDD_Rsfc.txt), R* (unitless, YYYYMMDD_Rstar.txt), temperature (degrees C, YYYYMMDD_Temp.txt), zonal wind speed (m s^{-1}, YYYYMMDD_u.txt), last data point zonal wind speed (m s^{-1}, YYYYMMDD_U.txt), meridional wind speed (m s^{-1}, YYYYMMDD_u.txt), last data point meridional wind speed (m s^{-1}, YYYYMMDD_U.txt), vertical velocity derived from the differential pressure fall speed (m s^{-1}, YYYYMMDD_w_accel.txt), vertical velocity using Method 1 in Nelson et al. (2017) (m s^{-1}, YYYYMMDD_w_M1.txt), vertical velocity using Method 2 in Nelson et al. (2017) (m s^{-1}, YYYYMMDD_w_M2.txt), vertical velocity using Method 3 (M3) in Nelson et al. (2017) (m s^{-1}, YYYYMMDD_wind.txt), vertical velocity (M3) with a 5 m s^{-1} differential pressure fall speed screening (m s^{-1}, YYYYMMDD_w5.txt), and vertical velocity (M3) with a 1 m s^{-1} differential pressure fall speed screening (m s^{-1}, YYYYMMDD_w1.txt).

In addition, comma separated value files for each date are created (YYYYMMDD_all_data.csv) and contain information on altitude (Alt, km), pressure (Press, hPa), latitude (Lat, degrees), longitude (Lon, degrees), azimuth (AZ, degrees), shear relative azimuth (AZ_SR, degrees), distance (Dist, km), RMW normalized radius (R_star, unitless), and vertical velocity (M3) with a 1 m s^{-1} differential pressure fall speed screening (w1, m s^{-1}).

The XDD_Merged.R code creates a comma separated value file (TCI_VV.csv) in the "…/XDD_VV/Output/Plots/Total/" directory containing altitude, pressure, latitude, longitude, zonal distance, meridional distance, azimuth, shear relative azimuth, distance, R*,

vertical velocity from M3, vertical velocity from M3 with a 5 m s^{-1} differential pressure fall speed screening, vertical velocity from M3 with a 1 m s^{-1} differential pressure fall speed screening, vertical velocity from M3 using the differential pressure fall speed, GPS fall speed, differential pressure fall speed, temperature, and relative humidity. The data inside the TCI_VV.csv file are for all data within 10R*, below 17.5 km, and for all days analyzed in Nelson et al. (2017).

EXPECTED ERRORS

When running XDD_VV.R for data for an individual date (e.g., all data for Marty on 27 September 2015), errors may occur including:

1. "ERROR: Rejection flag is turned off. If you wish to execute, please turn rejection flag to 1 in the Master_control.R script"

This error is expected and does not affect the successful execution of XDD_VV.R.

When running XDD_VV.R for storm data (e.g., all data for Marty), errors may occur including:

1. Warning message: package 'pracma' was built under R version X.X.X
2. Error in eval(ei, envir) : object 'Merged_flag' not found
3. In addition: There were 28 warnings (use warnings() to see them)
    a. After using warnings(), you would see: In eval(ei, envir) : NAs introduced by coercion

These errors are expected and do not affect the successful execution of XDD_VV.R. The first error is a warning, which informs the user the version of R in which 'pracma' was built. The second error occurs when the Merged_flag is set to 0. The third error is a warning, because the data extraction 'pads' some of the data with NA's, which are later removed.

When running XDD_VV.R for all merged data (e.g., all data), errors may occur including:

1. There were 30 warnings (use warnings() to see them)

This error is expected and does not affect the successful execution of XDD_VV.R.

REFERENCES

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