Moist Static Energy in NOAA G-IV Atlantic Dropsondes

Document prepared June 26, 2024 by Jake Carstens to describe data and sample analysis scripts accompanying Kopelman et al. (submitted to GRL)

Introduction

TC-DROPS (Tropical Cyclone – Dropsonde Research and Operations Product Suite, Nguyen et al. 2019) is an ongoing project synthesizing more than 25 years of quality-controlled GPS dropsonde data. Along with the traditional meteorological variables that dropsondes collect data on (i.e. temperature, pressure, wind, humidity), TC-DROPS adds valuable external information such as TC intensity and location, underlying sea surface temperature, and environmental vertical wind shear. This makes TC-DROPS ideal for composite analysis of TC thermodynamic structure.

While the dataset is considered experimental by its lead developer, Jonathan Zawislak (Jonathan.zawislak@noaa.gov), efforts are underway to formally publish the dataset. Here, we describe a condensed data file containing moist static energy, its relevant inputs, and storm metadata necessary for compositing over all dropsondes released for North Atlantic TCs from the G-IV (upper-level synoptic surveillance) reconnaissance aircraft. This file is available in both .mat and .nc format. Example MATLAB analysis scripts, requiring only limited adaptations to reproduce all manuscript figures directly, are also included and described here. For questions on this derived dataset, as well as suggestions on inputs to TC-DROPS for the eventual operational version (which I am contributing to), email me at carstens@psu.edu.

The Data

The full experimental TC-DROPS files produced by JZ are in netCDF format, and can be requested through him. For straightforward column integration of MSE between two pressure levels, I have used the version of the dataset that is remapped onto a standard pressure grid, spanning 50-1010 hPa in 5 hPa increments.

The data file is called TCDROPS_Basins_AL_Planes_GIV.mat (or .nc for the netCDF version). The .mat file is about 47.9 MB in size, and the .nc file is about 58.4 MB. This only considers dropsondes that meet the following conditions: 1) They have data; 2) They are launched in the vicinity of active TCs; 3) They are launched in the North Atlantic basin; 4) They are launched from the G-IV aircraft.

With one exception (discussed in variable list), there are only 2 dimensions: the dropsonde number (10,982, chronological), and the pressure level (193, increasing in pressure, or lowering in altitude). Any missing data are listed as NaN.

Additional Utilities

You will also find a collection of histograms, spatial heatmaps, and composite radius-pressure profiles of MSE. Corresponding functions used to generate these figures are included in the "Functions" subdirectory, which have been commented to describe the required inputs, the intended outputs, and their workflow. The storm-relative (radius/azimuth) "heatmaps" function can also be adapted to plot column-integrated MSE and other useful variables in polar coordinates, such as in Figure 1 of the Kopelman et al. manuscript. I have also included the functions written to calculate MSE, perform additional quality controlling, create the data files, and to extract wind radii from the Extended Best Track Dataset (Demuth et al. 2006).

The Variable List

Below, you will find a description of each variable, including the data type, its dimensions, and information about how it is computed.

Group 1: Variables Directly Measured by the Dropsondes – With the exception of pressure, these are 2-D variables where (x,y) → (sonde_number,vertical_level). The first vertical level is 50 hPa, so pressure increases as we progress through that dimension.

1. **pressure** (integer) – The vertical coordinate in intervals of 5 hPa.
2. **height** (integer) – The altitude of the sonde at a given pressure level (m).
3. **temperature** (float) – The temperature recorded by the sonde at a given pressure level (K).
4. **mixing_ratio** (float) – The water vapor mixing ratio (kg/kg) recorded by the sonde at a given pressure level.
5. **mse** (float) – The moist static energy (J/kg) at a given pressure level, computed from height, temperature, and mixing_ratio using script 'calculate_mse.m'.

Group 2: Variables Derived from Best Track TC Data – This will consider factors like TC position (and therefore, radius/azimuth), motion, intensity, and intensification rate. NOTE: Radius and azimuth are calculated by interpolating the center position to the time of the dropsonde observation. However, most other information in this group is simply set at the nearest best track time. In other words, an observation at 2034Z would use a best track intensity at 1800Z. ANOTHER NOTE: When possible, the radius of maximum wind is determined from SFMR observations. Otherwise, I input it from the Extended Best Track Dataset (Demuth et al. 2006) at the nearest best track fix time.

1. **mslp** (integer) – TC's minimum pressure (hPa) at the nearest best track fix. 1-D array based on the dropsonde number.

2. **vmax** (integer) – TC's maximum wind speed (in 5-knot increments) at the nearest best track fix. 1-D array like above.
3. **vmax_24** (integer) – TC intensity change (in 5-knot increments) in the 6 hours after the nearest best track fix time. In other words, assessment of future intensity change. 1-D array based on the dropsonde number.
4. **rmw** (integer) – TC's radius of maximum winds (km) at nearest best track time.
5. **rad** (float) – Radius (km) of the dropsonde from the center at each point along its descent. 2-D matrix (sonde_number,vertical_level). When possible, this is calculated using the center from HRD's 2-minute resolution tracks. Otherwise, it is interpolated linearly from the regular best track data.
6. **azi** (float) – Azimuth (˚ clockwise from north) of the dropsonde relative to the TC center, at each point along its descent.
7. **lmi** (integer) – Lifetime maximum intensity (knots) of the TC corresponding to a particular dropsonde. 1-D array.
8. **n_hours_from_lmi** (float) – Number of hours between dropsonde launch time and time that LMI for the appropriate TC is recorded in best track observations. Values are negative if the dropsonde is launched before LMI. 1-D array.

Group 3: Variables Derived from Environmental Factors – This group centers around wind shear (taken from SHIPS, DeMaria et al. 2005), and sea surface temperature (taken from the NOAA OISST dataset, Huang et al. 2021). Like the above, these are considered at the nearest available observation time from the respective datasets, rather than being interpolated.

1. **azi_shr** (float) – Same as azi, but after being rotated with the shear vector. 2-D matrix at each vertical level along the sonde's descent.
2. **shear** (integer) – Deep-layer (850-200 hPa) vertical wind shear magnitude in knots. 1-D array. Shear is calculated using a vector difference between 850 and 200 hPa winds in a 0-500 km annulus around the storm, after the vortex flow is removed.
3. **sst** (float) – Sea surface temperature (˚C) near the TC center at the time of the dropsonde launch. 1-D array.

References

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