Consistent Quality Control of 13-year (1996-2008) High Resolution GPS Dropsonde Data for Hurricane Research

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ABSTRACT

The primary application of dropsonde data is use in studying and helping predict the path and intensity of hurricanes. The primary objective of this project is to compile thirteen years (1996-2008) of high resolution dropsonde data, from NOAA's National Hurricane Center and Hurricane Research Division, NCAR's Earth Observing Laboratory, the United States Air Force, and NASA, in regions where hurricanes typically develop, and to apply consistent quality-control in order to produce a high-quality, long-term dropsonde climatology. This data may be used to characterize the thermodynamic and kinematic structure of different regions within a hurricane, and also to validate both satellite and reanalysis data.

Dropsondes are deployed from aircraft, most commonly over oceans, and they collect data at a half second rate as they descend, measuring pressure, temperature, relative humidity, and GPS winds. Between 1996 and 2008 two hundred fourteen storms formed in the Atlantic and Eastern Pacific Oceans, ranging in size and strength from tropical depressions to hurricanes, and roughly 16,500 dropsondes were deployed. Processing of these data will include running them through an established set of quality control procedures, and using statistical software for data analysis in order to investigate special problems that may affect data quality. Special attention will be paid to try to improve the dropsonde water vapor profile. Consistent QC of the dropsonde soundings will provide researchers with a unique dataset that will facilitate further understanding of hurricane dynamics by providing an opportunity to examine trends and characteristics of environments conducive to hurricanes.

1. DROPSONDE DATA PRODUCTS

The National Center for Atmospheric Research (NCAR) GPS dropsonde system is currently installed on over 20 aircraft around the world. The utilization of these instruments has allowed researchers to obtain comprehensive observations of the internal dynamics, structure, and evolution of tropical storms, which were previously unattainable due to safety concerns and instrument limitations [1]. Between 1996 and 2008 there were over 16,500 dropsondes deployed by NCAR, NOAA, the US Air Force and NASA (Table 1). Two hundred fourteen storms formed in the Atlantic basin between 1996-2008, ranging in size and strength from tropical depressions to hurricanes. The Hurricane Research Division (HRD) at NOAA routinely deploys dropsondes on their reconnaissance missions to help predict the path and intensity of hurricanes. NCAR, NASA and Air Force dropsonde missions are project specific, so the bulk of the soundings contained in this archive are from NOAA's National Hurricane Center (NHC) and HRD.

Dropsondes capture high resolution vertical atmospheric profiles of pressure, temperature, relative humidity (RH), wind speed wind direction and GPS altitude at a half-second rate. After ejection from the aircraft, typically around 4 km, the dropsondes elapsed flight time is approximately 7 minutes. They descend at approximately 25 m/s at flight level, slowing to approximately 10 m/s, as they pass through thicker air, before reaching the surface.

Table 1. Shows the approximate number of soundings collected by different organizations between 1996 and 2008

Agency	Number of Soundings
NOAA (HRD)	11427
NCAR	426
Air Force	4773
NASA	184

2. QUALITY CONTROL MEASURES

The first objective of this project is to make available a research quality dropsonde dataset that may be used for long-term studies of hurricane environments. The raw dropsonde data archive is undergoing a consistent set of quality control (QC) procedures that will conservatively remove erroneous data, while retaining finer features of the profiles. The QC steps broadly include, examination of the individual raw data profiles for obvious problems; automated processing through NCAR's Atmospheric Sounding Processing Environment (ASPEN) software, which quality-controls, performs smoothing, and removes suspect data points; examination of time series plots, of each parameter, to examine the consistency of soundings launched during each flight, and to show the variability of soundings from different missions; and finally, examination of the each quality controlled sounding profile. We will also take care to address errors related to fast falling dropsondes, those that do not transmit to the surface, and those which exhibit evidence of a wet-bulb effect, caused by wetting of the RH sensor after passing through a cloud.

© *Proceedings of the 8th International Symposium on Tropospheric Profiling, ISBN 978-90-6960-233-2*
Delft, The Netherlands, October 2009. Editors, A. Apituley, H.W.J. Russchenberg, W.A.A. Monna

3. IMPROVING THE MOISTURE PROFILE

Moisture is thought to be an important driving force in storm intensity changes. In the research community, there remains some doubt as to the accuracy of the relative humidity sensor because contamination of the sensor by outgasing of the dropsondes packaging material, if stored for long periods of time, has been known to occur. Additionally the accuracy of the sensor is only to within +/- 5%.

Attempts will be made, during processing of the sounding archive, to improve the moisture profile by first evaluating sensor performance (where possible), and then addressing issues related to dry bias of the sensor and wet bulb effect. In order to examine the accuracy of the RH sensor, one possibility that will be explored is to generate comparisons between dropsonde measured RH near landfall and GPS ground based precipitable water measurements over land. This may be complicated by the high variability of moisture within a storm, or by an absence of dropsondes deployed near or over land, but it is something we plan to investigate. Next, we will address instances where the dropsondes RH sensor measured less than 100%, but was known to have passed through a cloud. HRD has adopted a correction scheme for dropsondes that assumes a maximum RH of 100%, subtracts the maximum RH measured by the dropsonde, and multiplies the ratio of the measured RH to the maximum RH:

(1) Correction = 100% - RHmax * (rh/RHmax)

With this approach, increased scaling is done at higher humidities where larger errors occur. The last issue to be resolved, with regard to humidity, is a lag of the sensor after exiting a cloud, also known as a wet-bulb effect. The time it takes for the sensor to dry out, known as the evaporation time, varies but likely increases with cloud thickness and the liquid water path, which are indicators of the amount of water on the sensor. Alternate heating of the twin humidity sensor (currently on, but not implemented in the dropsonde) might help speed up the evaporation of water [3], providing a more precise indication of the cloud base. An accurate response time of the RH sensors is essential to determine cloud top height, base and cloud layer depths.

4. CHARACTERIZATION OF STORM REGIONS

A longer term objective of this project is to work closely with hurricane researchers to characterize the thermodynamics in and around hurricanes in order to document features unique to different storm regions. Inter-comparisons between dropsondes are complicated because the instruments tend to drift apart due to the turbulent nature of the environment [2]. In characterizing the various regions of a storm it will be important to examine not only where the dropsondes entered the storms, but the path they travel and the location where they hit surface. Dropsonde launch locations will be overlaid onto infrared satellite images (Figure 1) to determine the region of the storm that the dropsondes entered. Spatial analysis will be performed by incorporating soundings into contour plots and synoptic maps, which will allow for examination of different vertical levels. Use of first guess reanalysis data assimilation, may also prove highly valuable in assisting with spatial analysis of these tropical storms.

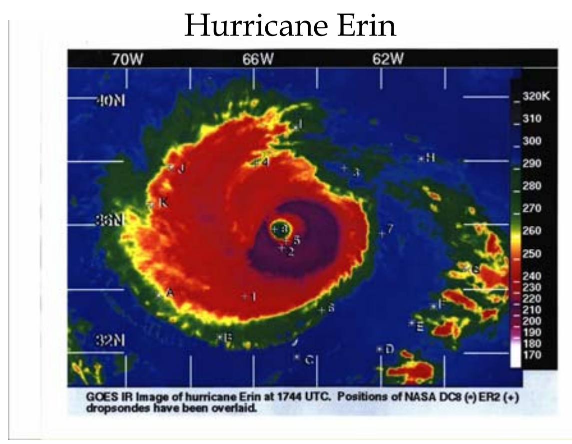

Figure 1. shows dropsonde launch locations overlaid on an infrared satellite image of Hurricane Erin in 2001

5. CONCLUSIONS

Improvement in the moisture profiles from these dropsondes would be an important step in enhancing dropsonde data quality, and would encourage further utilization of dropsonde humidity data for modeling and for weather and climate research. Two possible options to explore would be: investigation and application of a correction algorithm that could be applied to dropsondes which knowingly traveled through clouds, and applying a correction to account for the time lag of the RH sensor, providing more accurate detection of cloud top and base heights.

Once complete this dataset will serve as an invaluable tool for hurricane researchers. It will facilitate further understanding of hurricane dynamics by providing a unique long-term, high resolution dataset for use in climatological studies. Additionally, it will enable researchers to better define characteristics unique to different regions within a storm, to document common large and small scale structures, and to improve understanding of the thermodynamic, structures that influence tropical cyclone tracks, intensity and precipitation forecasts.

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