17A.1 Vertical Profiles of Thermodynamic variables in Hurricanes Bonnie (1998) and Mitch (1998): Implications for Energy Transport in the Inflow Layer

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1. Introduction

The GPS sonde, with its 2 Hz sampling, provides 6-7 m vertical resolution in the inflow layer to a hurricane. We use 85 sondes deployed in Hurricane Bonnie (964 hPa) and 40 sondes dropped mostly around the eyewall of Hurricane Mitch (930 hPa). Our goals are to: (1) determine which thermodynamic structures are real, and, (2) interpret these structures in light of the energy transfer into the inflow layer, which is vital to the intensity of the hurricane. We believe that we can gain a better understanding of the role of spray, currently argued to play a major role in the enhancement of the energy content of the inflow.

Byers (1944) postulated, largely with only a small amount of observations, that the low-level inflow to the hurricane is isothermal. Korolev et al. (1990) and Pudov (1992) argue that spray evaporation dramatically cools the inflow layer. Cione et al. (2000) and Barnes and Bogner (2001), using buoy observations and Omega dropwindsondes (ODWs), respectively, argue for the importance of downdrafts. These latter two studies combine data from numerous storms, and essentially create a composite analysis. There continues to be some debate as to the efficacy of their findings, given the challenging conditions that the sensors must face. All the aforementioned papers have shed doubt on the Byers postulate.

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At the conference the emphasis will be on the temperature sensor.

2. Data

Hurricane Bonnie was sampled as it made landfall in North Carolina. Two NOAA WP-3Ds deployed GPS sondes over 11 h. We have developed storm relative maps at multiple levels of the thermodynamic variables and believe that we can resolve spatial scales approaching 20 km in much of the storm. We have also examined the data in the vertical, and as a function of wind speed.

Mitch was sampled by a NOAA WP-3D and Air Force C-130. The drops are concentrated in and around the eyewall. The inclusion of the Mitch data allows us to view conditions in a category 4 hurricane.

The GPS sonde, besides offering the superior vertical resolution, does not suffer as much from passing through saturated layers, in contrast to the far less successful ODWs.

3. Preliminary Results

The horizontal maps of temperature in Bonnie can be correlated with reflectivity data from the WSR-88Ds at Morehead City and Wilmington. Three main points can be made. First there is cool air collocated with the upwelled water in the right rear quadrant of the storm. Here we have compared the 10 m T field with a SST map developed from 13 AXBTs. Second, there is a cool annulus collocated with the eyewall. The collocation with the intense echoes favors downdrafts as the leading cause. Third, the warm air streaming from the continent cools as it approaches the eyewall. Air in the offshore flow does not contain any reflectivity, but does have relative humidity (RH) of 70 to 80% and wind speeds in excess of 18 m/s. This makes a strong case for the dry air being cooled by the evaporation of spray, and not downdrafts. In the eyewall region relative humidity often exceeds 95%. Such a high RH inhibits evaporation of spray and attendant cooling.

The vertical profiles of potential temperature can be used to determine a mixed layer height. Over 80% of the Bonnie drops show a mixed layer, and almost all of the remaining drops are stable to the surface. Higher mixed layers are in the offshore flow, while the stable or very low mixed layers are collocated with the high reflectivity of the eyewall or convective bands that are to the north and east of the circulation center. The performance of the temperature sensor is reliable enough to create a mixed layer map for the storm.

Adjacent to the sea surface there are three profiles that describe the majority of the situations. First, and most frequently, the profile remains dry adiabatic from the LCL down to the sea. Second, about 13% of the profiles manifest cooling in the lowest 10's of meters. The cooling is typically quite small, on the order of a few tenths of a degree. The cause could be wetting of the sensor by spray, or cooling of the surface layer by the evaporation of spray. Most of these again occur in RH > 95%. The layer departing from dry adiabatic is thin and therefore unlikely to be due to downdrafts.

The third type of profile also departs from dry adiabatic, but here the structure becomes superadiabatic. Temperature profiles in the very high wind regime found in Mitch exhibit a deeper superadiabatic layer than those observed in Bonnie. We interpret these profiles as supporting evidence that spray droplets, which should become more numerous in high winds, are rapidly surrendering their sensible heat to the atmospheric surface layer. The observations support the arguments of Andreas (1995) who showed two different time scales for spray – the droplets rapidly cool to air temperature but evaporate much more slowly.

At the conference the observations will be used to place the results of Byers, Cione et al., Korolev, and Barnes and Bogner in a unifying context.

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