Historic Flooding from Hurricane Diane August 1955

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1. Introduction

Hurricane Diane followed just behind Hurricane Connie, becoming the second hurricane of the 1955 North Atlantic Hurricane Season. Diane first reached tropical storm intensity late on 9 August 1955, while it was still a few hundred miles northeast of the Leeward Islands. Diane began to strengthen as it passed well to the north of the Caribbean Islands. On 12 August, Diane reached peak intensity with maximum sustained winds of 120mph and a minimum central pressure of 969mb. At this time, a ridge of high pressure began to build to the north of Diane, and as a result, the storm's heading changed from a northward track to a more west and northwest track. This change in direction would bring Diane back towards the East Coast of the United States on the heels of Hurricane Connie.

After weakening over the colder waters of the northern Atlantic Basin, Diane made landfall just south of Wilmington, NC in Carolina Beach as a category 1 hurricane on 17 August 1955. Diane's landfall occurred only five days after Connie had made landfall, less than 100 miles to the north. Diane weakened to a tropical storm shortly after landfall, and unlike Connie, Diane began to recurve back towards the northeast shortly thereafter. By 0600 UTCC on 19 August 1955, Diane had moved right over the New York City Metropolitan Area. Diane would continue on a rapid east-northeast track, which would bring the center of circulation through all of Long Island and just to the south of Cape Cod. Diane would eventually clear the Eastern Seaboard and become extratropical later on 20 August 1955.

As was the case with Connie, heavy rainfall from Diane (Figure 1) led to significant damage across the Mid-Atlantic and New England. The flooding in these two regions

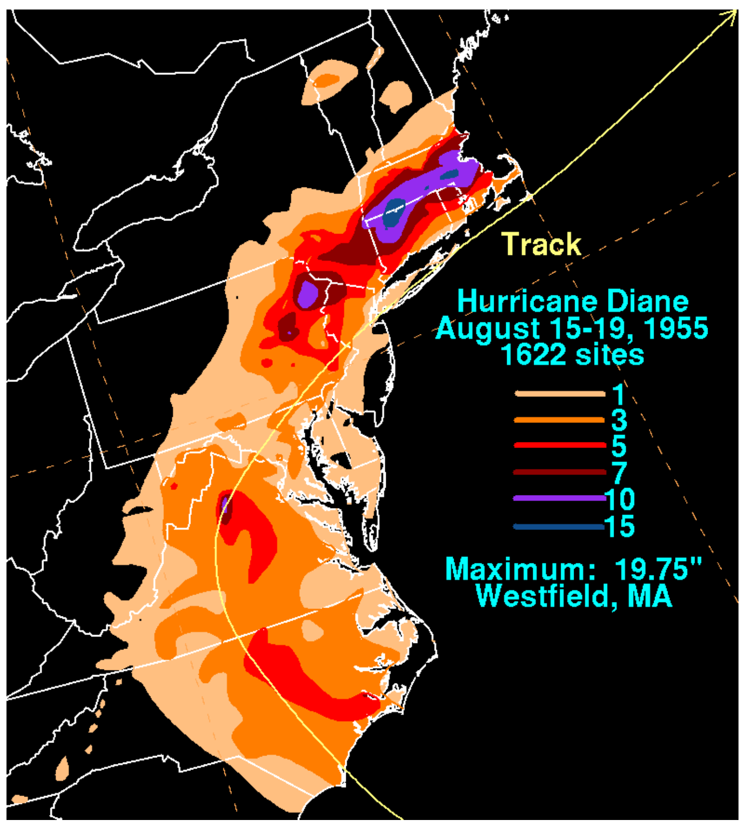

Figure 1. Rainfall map from the Hydrometeorological Prediction Center that were constructed using data from the National Climatic Data Center.

amounted to $832 million in damage and over 200 fatalities. This made Hurricane Diane the costliest storm on record, until Hurricane Betsy struck southern Florida and the Gulf Coast in September of 1965.

This study will analyze the large scale patterns associate with Hurricane Diane. By analyzing various climatic anomalies in the large scale pattern, this study will address whether or not Diane shares common characteristics that are often found in Mid-Atlantic heavy rainfall events (Table 1). Furthermore, this study will focus on the historic flooding caused by this storm. Through a comparison between Diane and Connie, this study will show that the magnitude of a flood event depends on more than just heavy rainfall.

2. Methods

The 850 hPa heights, 1000 hPa precipitable water, and other standard level fields were derived from the NCEP/NCAR data set. The means and standard deviations used to compute the standardized anomalies were from the NCEP/NCAR data as described by Hart and Grumm (2001). Anomalies were displayed in standard deviations from normal, as standardized anomalies. All data were displayed using GrADS (Doty and Kinter 1995).

The standardized anomalies are computed as:

$$SD = (F - M)/\sigma \quad (1)$$

Where **F** is the value from the reanalysis data at each grid point, **M** is the mean for the specified date and time at each grid point and σ is the value of 1 standard deviation at each grid point.

The precipitation images and the ranking of the top 5 November rainfall events in Table 1 were based on the UPD data from 1 January 1948-1 October 2010. The maximum rainfall over the 24 hours ending at 1200 UTC daily was used to find these data. These data are heavily biased toward COOP reports, but they represent the longest running continuous record from which these records can be easily estimated.

The National Hurricane Center's best-fit track database (HURDAT) was utilized to examine Connie's track and intensity (Jarvinen et at 1984).

For brevity, times will be displayed in day and hour format such at 12/1200 UTC signifies 12 August 1955 at 1200 UTC.

3. Results

i. Large-scale pattern

Hurricane Diane reached category three intensity over the Central Atlantic, just one day after Hurricane Connie had made landfall in North Carolina. Diane would retain category three intensity for 60 hours ending at 15/0600Z. Diane would steadily weaken after this, as cooler air moved in from the east and Diane moved over the cooler waters of northern Atlantic

As Diane was strengthening from 11-12 August, the storm had slowed down and taken a turn to the north-northeast. However, a dominant Bermuda High abruptly turned the storm back to the west early on 13 November. By 14/1200 UTC, the ridge of high pressure had extended into the northeastern United States. As a result category one Hurricane Diane was steered towards the eastern United States, and into the Carolina coastline just before 17/1200 UTC (Fig. 2e).

Similarly to Hurricane Connie, Diane did not interact with an approaching Maddox synoptic or frontal system as do most TCs that affect the Mid-Atlantic (Maddox 1979). This allowed Diane to dig through Virginia 24 hours after making landfall. Meanwhile, the Bermuda High finally began to weaken. This allowed Diane to recurve back to the east through the New York Metropolitan area and across Long Island and eventually Nantucket Island.

As is typical with strong tropical systems, Diane had anomalously high precipitable water content and wind speeds as well as anomalously low mean sea surface pressures. Figures 2-4 show the evolution of this general pattern. An analysis of these data shows that Diane contained many elements that are common in most heavy rainfall events. A closed contour of 60mm of precipitable water moved inland with Diane by 16/0000 UTC (not shown). The precipitable water levels were more than 3 standard deviations above normal as the storm affected the eastern United States (Fig. 3).

The 850 hPa winds were 3-5 standard deviations above normal from 16/1800 UTC to 19/0000 UTC (Fig. 4), and as a result, the southerly and southeasterly winds over the eastern half of the storm helped keep the precipitable water values three or more standard deviations above normal through 19/0600 UTC.

ii. Rainfall and flooding impacts

Estimated storm total precipitation is shown in Figure 5. Additionally, 24 hour rainfall totals are shown in Figures 6 and 7.

Between 17/1200 UTC and 18/1200 UTC (Figure 6), widespread rain fell across much of the Mid-Atlantic and New England regions. The heaviest rain during this 24-hour time period fell in northern Virginia. Locally, rainfall exceeded 128mm, with a large closed contour of 64mm covering much of Virginia and regions of adjacent states.

During the next 24 hours, the rainfall shifted northeastward (Figure 7) as Diane pushed back to the north and east. The rainfall from Diane during this period encompassed the eastern half of Pennsylvania, New Jersey, southern New York, with the heaviest rain falling in southern New England. Much of Connecticut, Rhode Island, and Massachusetts received in excess of 128mm of rain during this 24 hour period.

This added up to a closed contour of 64mm of storm total precipitation along Diane's entire path from the Carolinas, through the Mid-Atlantic, and southern New England (Fig. 5). Embedded in this area are several large 128 closed contours, with rainfall exceeding 256mm in parts of southern New England. HPC lists a precipitation maximum of 19.75 inches in Westfield, MA. In the Mid-Atlantic region, the maximum 24 hour precipitation was nearly 139 mm between 18/1200 UTC and 19/1200 UTC. The rainfall on that date ranks 26th in our record of Mid-Atlantic heavy rain events (Table 1).

The rainfall from Diane helped to cause significant and widespread flooding across the Mid-Atlantic and New England states. Seventy different forecast points across seven different states in the Mid-Atlantic River Forecast Center's basin reached flood stage, with 33 of those points cresting in major flood stage[1]. Furthermore, multiple locations in the Delaware Basin crested at record high levels that have yet to be surpassed. This flooding would cause the vast majority of the $832 million in damage associated with Hurricane Diane.

4. Conclusions

Hurricane Diane was an extremely significant heavy rain event that caused historic flooding across the northeastern United States. As was the case with Hurricane Connie, *Diane was a primarily tropical rain event,* devoid of any other low pressure systems or frontal systems. It is not unusual for TCs to cause flooding, but it is rather uncommon for a mainly tropical system to cause heavy rain in the Mid-Atlantic. Most of the TCs that affect the region are a hybrid between a tropical system and either a Maddox synoptic or frontal type system. Thus, the majority of TCs in the Mid-Atlantic region typically interact with a north-south or east-west oriented frontal boundary. Purely tropical systems are far less common.

Additionally, *Diane perfectly illustrates that heavy rainfall does not directly correlate with significant flooding*. The rainfall from Diane across the Mid-Atlantic was significantly less than the rainfall associated with Hurricane Connie, just one week earlier. However, the flooding in the aftermath of Diane was much more severe than the rather minor flooding that occurred after Connie. This is evidence that there are many other factors that influences flooding, such as the melting of snow cover, soil saturation, and pre-storm river stage height. In this case, the significant rainfall from Connie did not cause much flooding, but instead raised river heights and saturated the soil. This allowed the less significant rains from Diane to flood much of the Mid-Atlantic. The circumstances in New England were different, as the rain from Diane was much more significant than the rainfall from Connie a few days earlier. Connie likely raised river stages and the extreme rainfall associated with Connie play a significant role in the flooding in New England. It should be noted rainfall totals north of Coastal Connecticut were not used to produce Table 1.

The rainfall associated with Connie was observed with strong low-level flow at 850 hPa and with 3SD above normal PW anomalies. This pattern of strong low-level winds and above normal PW values appears consistent with all the top 100 rainfall events in the Mid-Atlantic Region. This suggests using standardized anomalies may aid in anticipating potential heavy rainfall events.

[1] http://www.erh.noaa.gov/marfc/Rivers/FloodClimo/MARFCHistoricFloodEvents/1900sFloods/1955/1955-August18.pdf

5. Acknowledgements

We would like to thank the NWS SCEP program. The precipitation typing project was part of the local SCEP training program.

6. References

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NOAA Technical Memorandum NWS NHC 22, Coral Gables Florida, 21 pp.

Maddox, R. A., C. F. Chappell, L. R. Hoxit, 1979: Synoptic and Meso-α Scale aspects of Flash Flood Events1. *Bull. Amer. Meteor. Soc.*, **60**, 115–123.

Rank	Start Time	End Date	Max Precip (mm)	Classification	TC Names
1	12Z11AUG1955	12Z12AUG1955	193.849	Tropical	Connie
2	12Z08OCT2005	12Z09OCT2005	191.179	Hybrid	TS Tammy
3	12Z30SEP2010	12Z01OCT2010	182.574	Hybrid	
…					
23	12Z07OCT2005	12Z08OCT2005	143.003	Hybrid	TS Tammy
24	12Z26AUG2008	12Z27AUG2008	142.064	Hybrid	TS Fay
25	12Z27JUN2006	12Z28JUN2006	139.713	Synoptic	
26	***12Z18AUG1955***	***12Z19AUG1955***	***138.898***	***Tropical***	***Diane***
27	12Z11SEP1960	12Z12SEP1960	138.359	Hybrid	Donna
28	12Z06SEP2008	12Z07SEP2008	136.611	Hybrid	TS Hanna
29	12Z18AUG1991	12Z19AUG1991	136.244	Hybrid	Bob

Table 1: A table showing the top three rain events in the Mid-Atlantic, along with other relevant rain events. These events are ranked by maximum one location 24-hour rainfall from 12Z to 12Z. Each of these top events is classified as mainly tropical events, frontal type events, or a synoptic and tropical hybrid. The last column lists the tropical cyclone associated with the event if applicable.

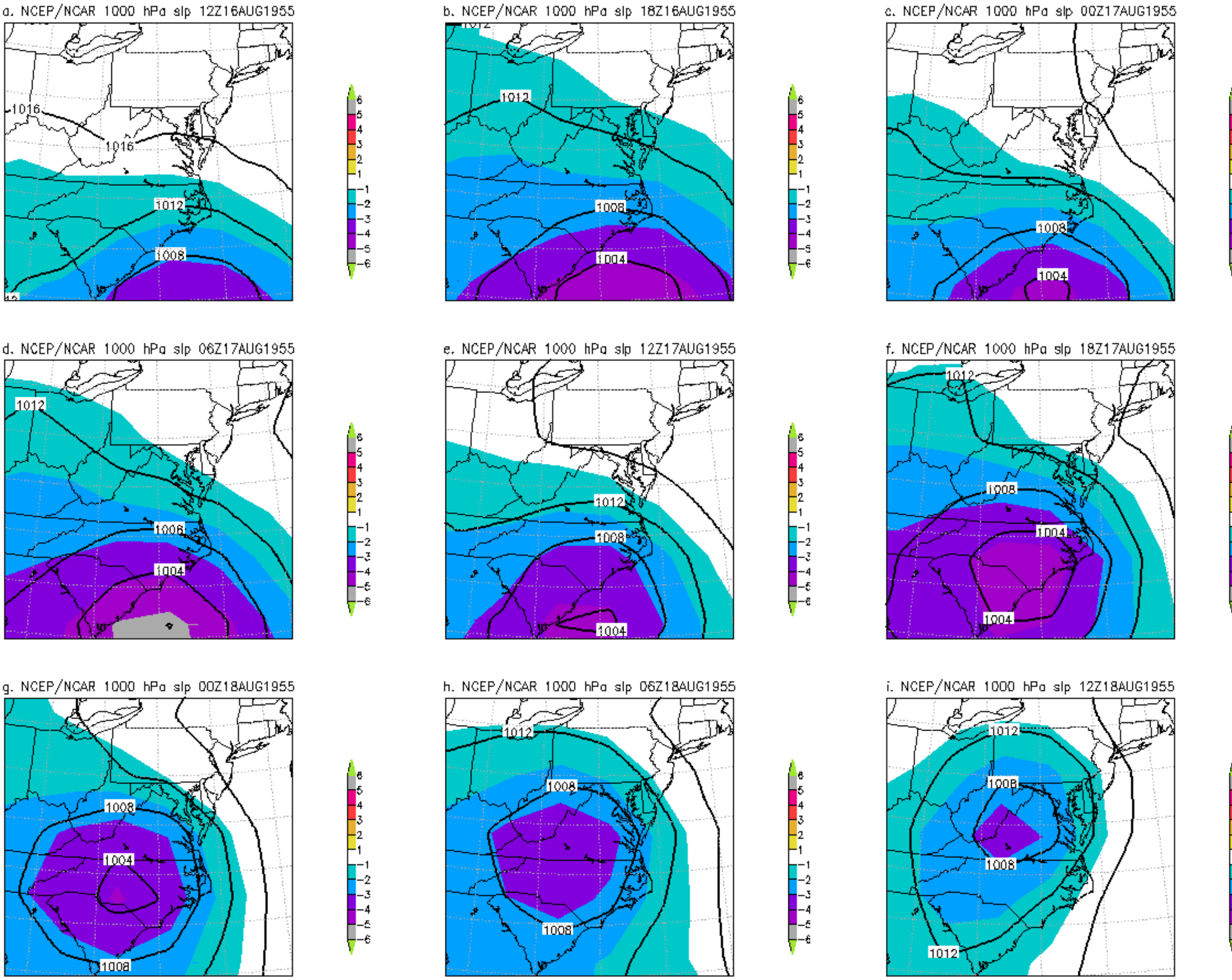

Figure 2: Atmospheric analysis valid from 1800Z 16 August 1955 to 1800Z 18 August over the Mid-Atlantic. The evolution of sea level pressure (hPa) and sea level pressure anomalies is shown as Diane moved through the region. Return to text.

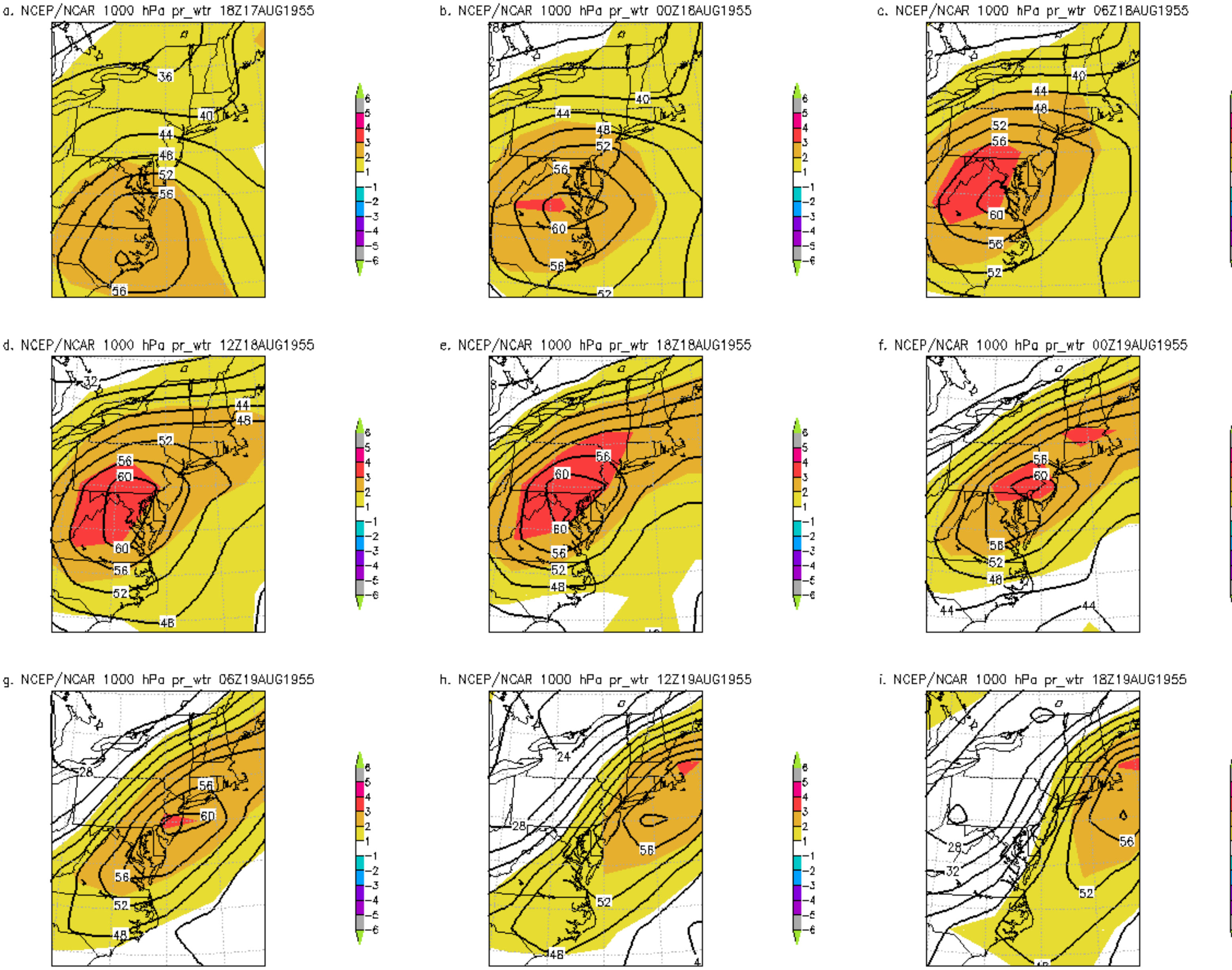

Figure 3: Atmospheric analysis valid from a) 1800Z 17 August 1955 to i) 1800Z 19 August over the northeastern United States. The evolution of precipitable water (mm) and precipitable water anomalies is shown as Diane moved through the region. Return to text.

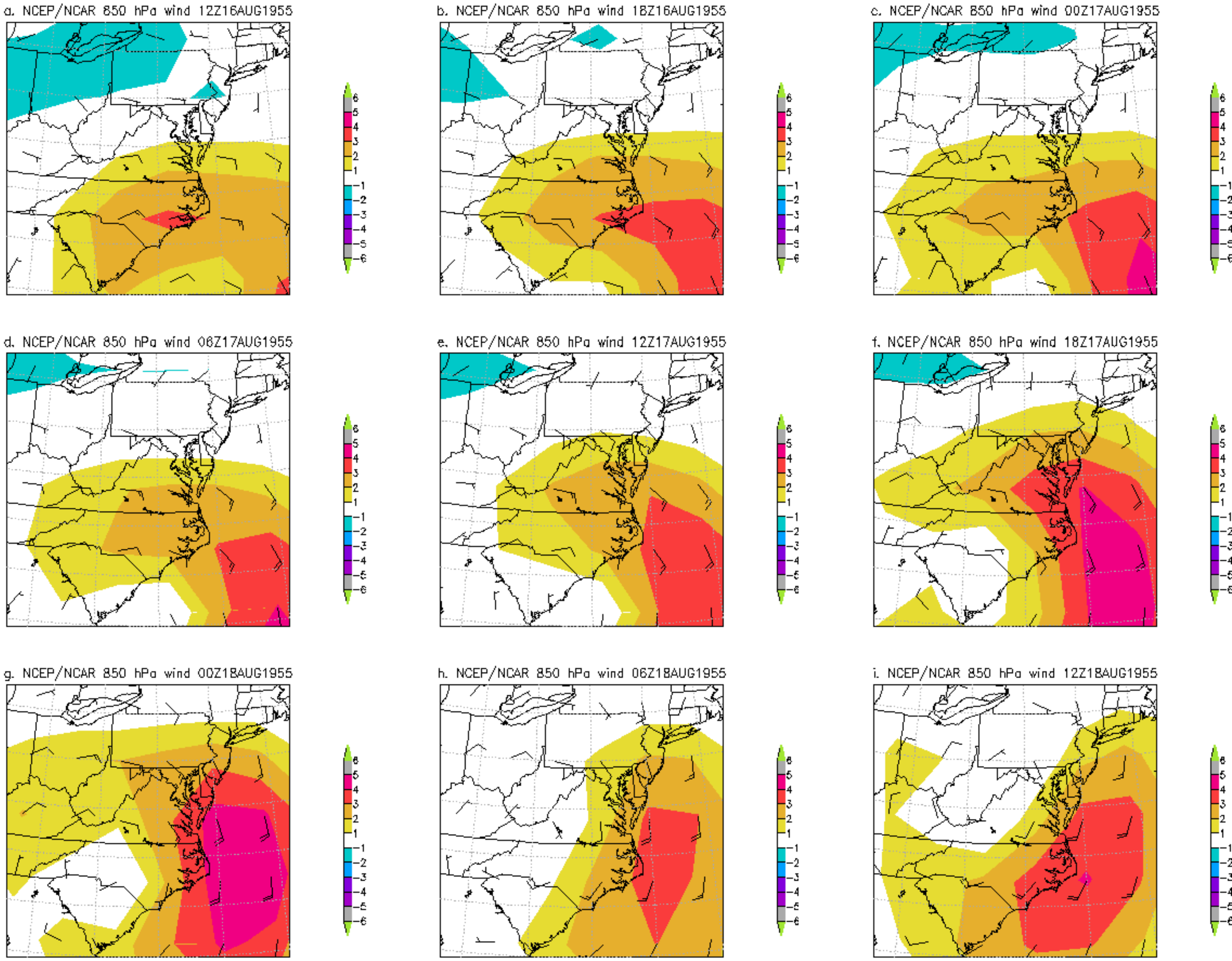

Figure 4: Atmospheric analysis valid from a) 1200Z 16 August 1955 to i) 1200Z 18 August over the Mid-Atlantic. The evolution of the 850 hPa winds (ms-1) and wind anomalies is shown as Diane moved through the region. Return to text.

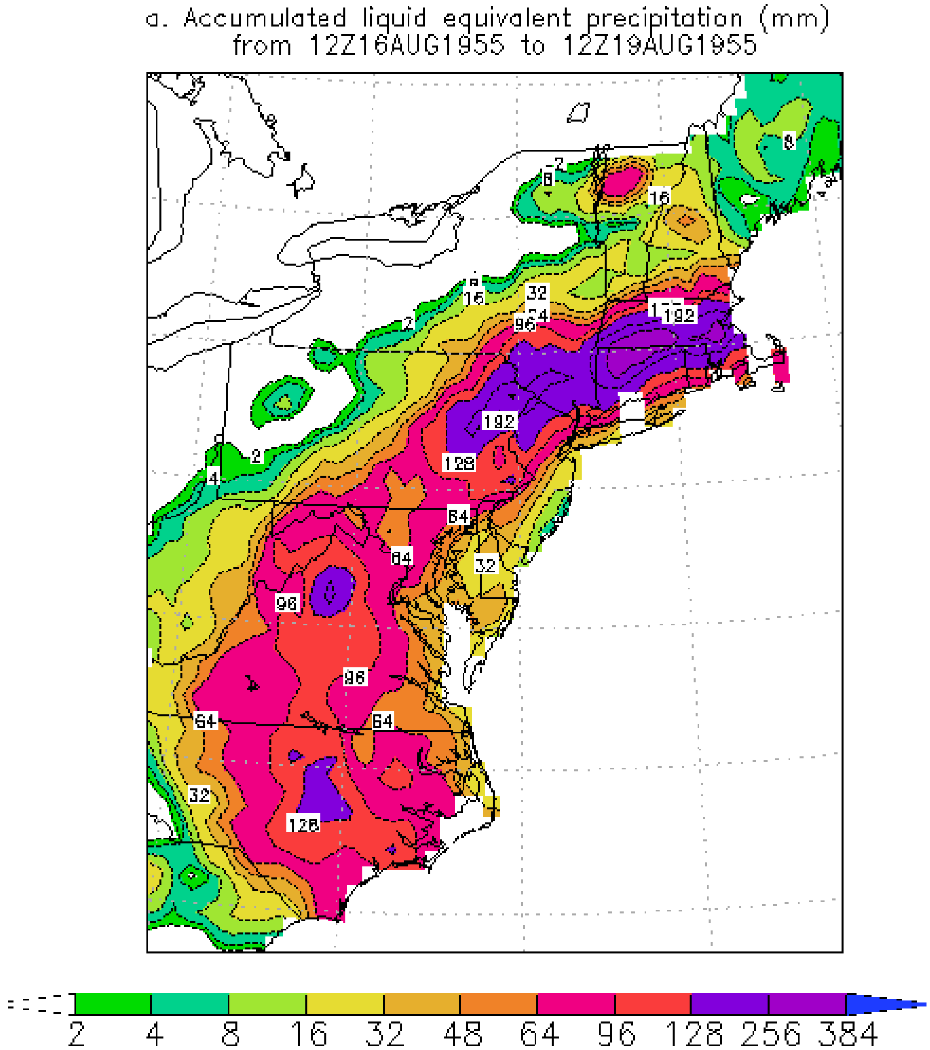

Figure 5: Estimated accumulated rainfall (in mm) during Hurricane Diane from 1200Z 16 August 1955 to 1200Z 19 August 1955. Return to text.

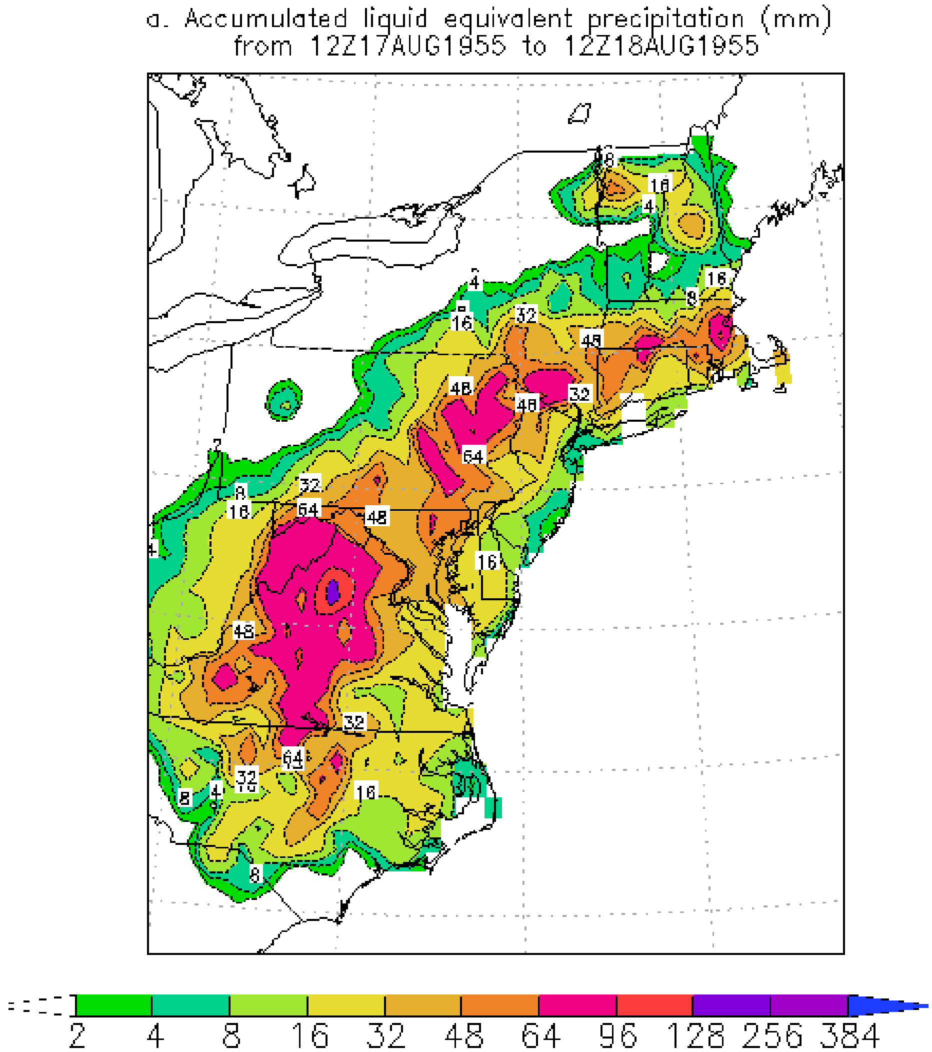

Figure 6: Estimated 24-hour accumulated rainfall (in mm) as Hurricane Diane moved inland from 1200Z 17 August 1955 to 1200Z 18 August 1955. . Return to text

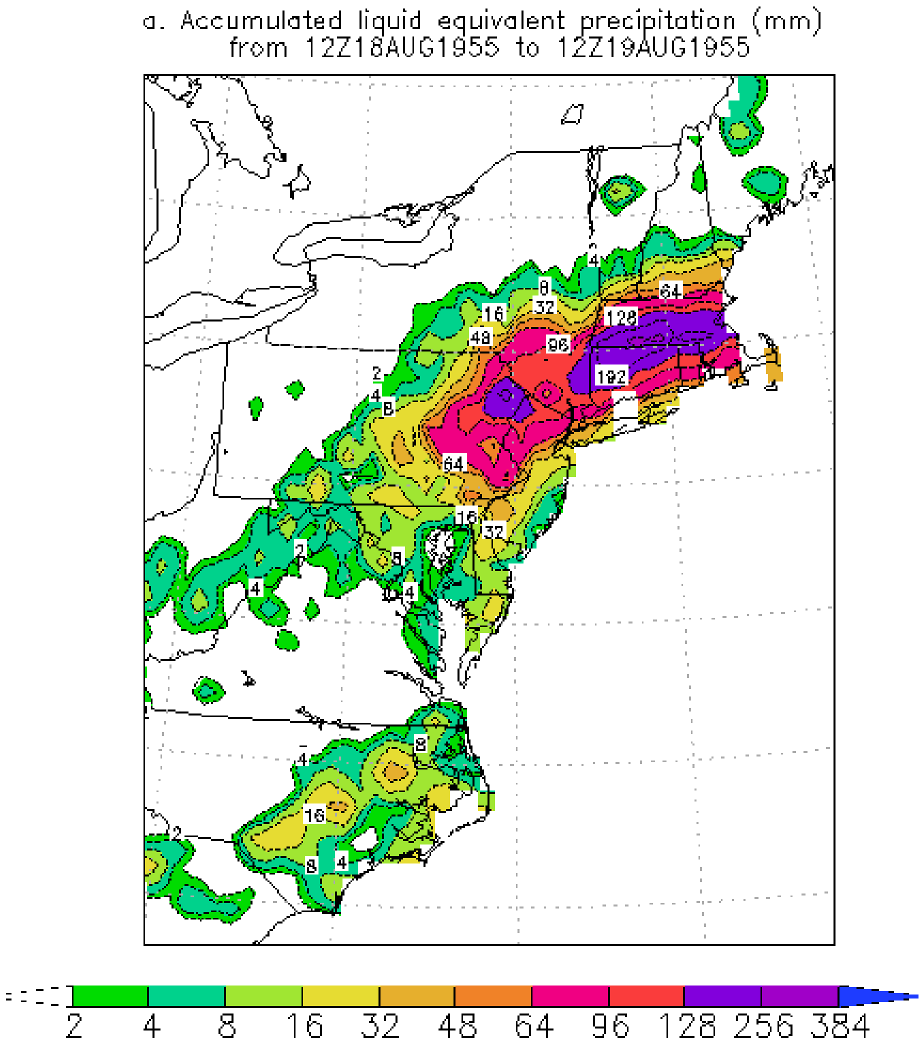

Figure 7: Estimated 24-hour accumulated rainfall (in mm) as Hurricane Diane moved through the Mid-Atlantic and New England states from 1200Z 18 August 1955 to 1200Z 19 August 1955. . [Return to text](#)