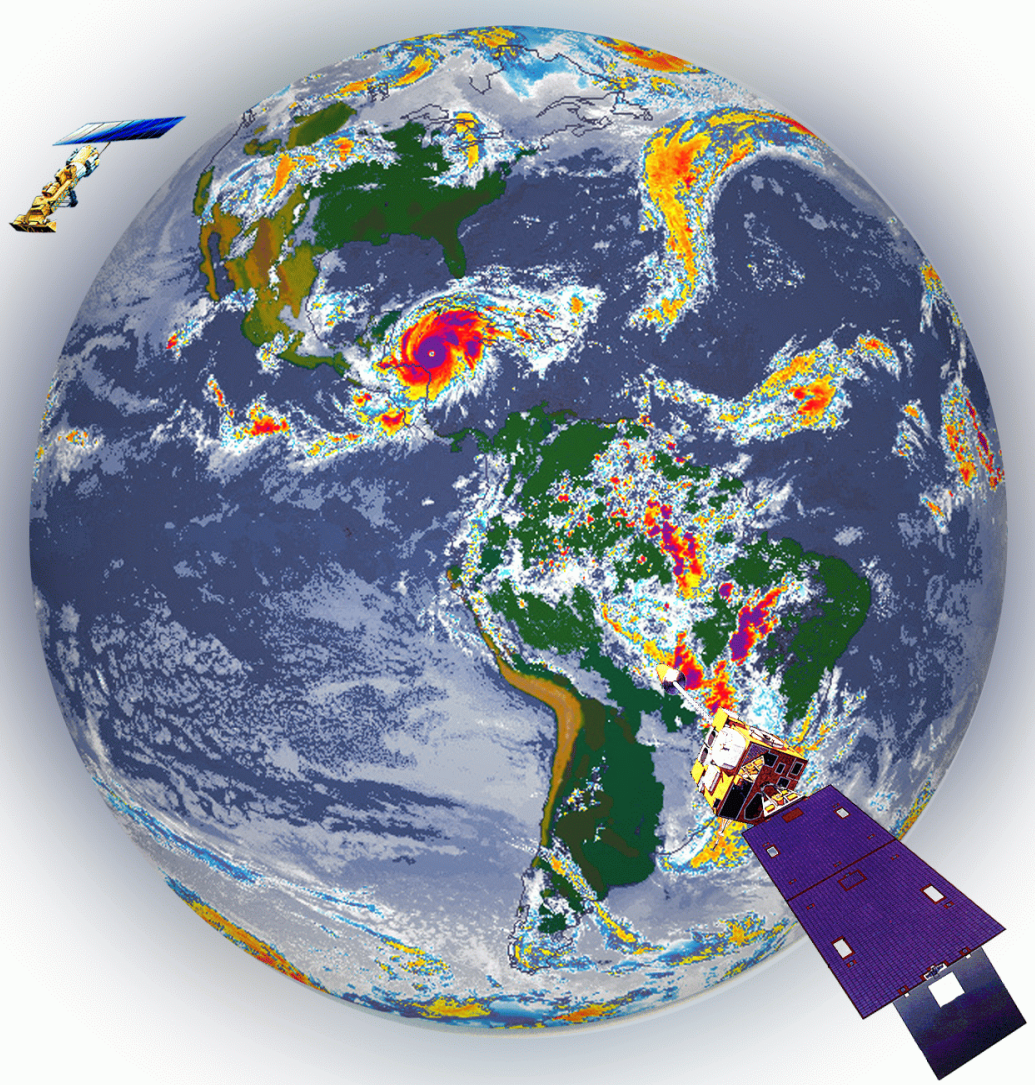
Technical Report 2000-03

1999 Atlantic Tropical Storms

Views from the NOAA Satellites



U.S. Department of Commerce
NOAA/NESDIS
National Climatic Data Center

Asheville, North Carolina
November 2000

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A. Graumann, N. Lott

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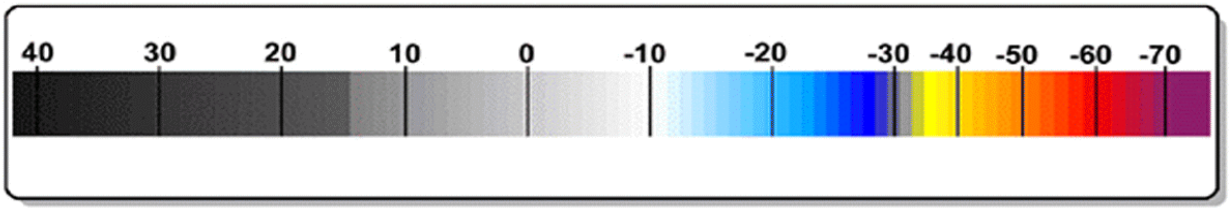
Introduction

This annual report is a summary of the 1999 Atlantic Hurricane season, and provides a synopsis of each named tropical storm using textual information obtained from the National Hurricane Center's *Summary of the 1999 Atlantic Season* report and the National Weather Service's *Preliminary Storm Data* reports with complimentary satellite imagery. The tables of station precipitation data were created from NWS cooperative and airport stations. The numbers for deaths and damages were obtained from several sources including the NHC Preliminary Hurricane Reports, Federal Emergency Management Agency (FEMA), and state emergency management agencies. These numbers are subject to revision.

The colorized satellite images from the GOES satellite were created using one of the long-wave infrared channels (~10.7Fm), which measures radiated energy from the earth and atmosphere. The radiance counts were calibrated and converted to brightness temperatures and then scaled to an arbitrary color range, which best displays clouds of various types and heights. The scale ranges from black, indicating the warmest surfaces, to maroon, indicating the coldest surfaces (fig. 1). Land and ocean surfaces are relatively much warmer than cloud tops, and hence, appear gray to almost black in the series of infrared images within this report. In some cases, appropriate coloring may be applied to land and ocean areas to further enhance the images. The visible satellite images were created using the GOES visible channel (.52Fm-.75Fm) which measures reflected energy in terms of albedo. The visible images are displayed in a gray scale (0-255). The color images from the polar-orbiting satellites were created from a combination of channels, namely, red for channel 1 - visible, green for channel 2 - near infrared, and blue for channel 4 - long-wave infrared. These images are frequently referred to as *multi-spectral false color images*. The satellite images within this report, along with many more tropical storm images, are on-line under the NCDC Satellite Resources section at http://www.ncdc.noaa.gov/ol/satellite/satellitedata.html

Figure 1 - Color vs. Temperature Scale (Degrees EC) for GOES Infrared Images



1999 Atlantic Hurricane Summary

The 1999 hurricane season had above normal activity with 12 named tropical cyclones, 4 of which were tropical storm strength (<64 mph) and 8 of which were hurricanes. This compares to the long-term average of ten named tropical cyclones: six hurricanes and four tropical storms. Table 1 lists these tropical cyclones along with their dates, minimum sea level pressures, maximum sustained wind speeds, category classes, U.S. dollar damages, and directly related deaths. Note that the total number of storm-related deaths is often higher.

Five of the eight hurricanes were major, falling in the Hurricane Saffir-Simpson Scale of 3 or higher with minimum sustained wind speeds of 96 knots or higher. Interestingly, all five of these strong hurricanes reached category 4 status having winds of at least 114 knots. This is the highest number of category 4 hurricanes in a single season since records began in 1886. The total activity over the past five years (1995-1999) included 41 hurricanes with 20 major hurricanes, which is also unprecedented.

Hurricanes Bret, Floyd, and Irene made landfalls on the U.S. mainland as category 3, 2, and 1 hurricanes, respectively. In addition, Harvey made landfall in the United States as a tropical storm. Dennis produced near-hurricane conditions on the U.S. mainland. There was one additional U.S. hurricane landfall in the Virgin Islands very late in the hurricane season, named Lenny.

The inland flooding from Floyd was a disaster of immense proportions in the eastern United States, particularly in North Carolina. The U.S. direct-death total of 56 due to Floyd, is the largest hurricane death total since Agnes, which killed 122 people in 1972, also due to inland flooding.

The Bahamas experienced tropical storm conditions from Dennis, and hurricane conditions from Floyd. Gert briefly produced hurricane winds at Bermuda and also affected Newfoundland. Cuba experienced tropical storm conditions from Irene. Tropical storm Katrina made landfall in Nicaragua. Lenny produced up to category 2 conditions over portions of the Leeward Islands of the Caribbean.

Lenny was a rare late-season hurricane; the first category 4 hurricane in November since Greta in 1956. Also, the track was unusual, in that the hurricane moved eastward through the Caribbean Sea. Lenny was the first hurricane to strike the islands of the Lesser Antilles from the west.

Table 1 - 1999 Atlantic Basin Tropical Storms and Hurricanes

	Name	Dates	Minimum Pressure (millibar)	Max Wind Speed (knots)*	Saffir-Simpson Scale**	Deaths ^	Damages#
1	Arlene	06/11-06/18	1008	50	n/a	0	none reported
2	Bret	08/18-08/25	944	120	4	0	$60 million
3	Cindy	08/19-08/31	944	120	4	0	none reported
4	Dennis	08/24-09/05	962	90	2	4	$157 million
5	Emily	08/24-08/28	1004	45	n/a	0	none reported
6	Floyd	09/07-09/17	921	135	4	57	$4.5- 6 billion
7	Gert	09/11-09/23	930	130	4	0	none reported
8	Harvey	09/19-09/22	994	50	n/a	0	$15 million
9	Irene	10/13-10/19	958	95	2	0	$800 million
10	Jose	10/17-10/25	979	85	2	2	none reported
11	Katrina	10/28-11/01	999	35	n/a	0	none reported
12	Lenny	11/13-11/22	933	135	4	13	$330 million

Legend to Table 1

* Estimated maximum 1-minute average wind speed.

** Saffir-Simpson Hurricane Scale. Indicates maximum strength of the storm during its lifetime. Categories: **1** (64-82 kts), **2** (83-95 kts), **3** (96-113 kts), **4** (114-135 kts), and **5** (over 135 kts)

^ Estimated number of deaths from direct causes. Does not include indirect deaths. Includes deaths in U.S., Caribbean, and Central America.

\# Damages are estimated based on several sources.

Following is a synopsis of each storm:

Arlene - Originating from the remnants of a front on June 11, about 550 statute miles southeast of Bermuda, Arlene formed just 11 days into the hurricane season. Wind speeds reached a maximum of 50 knots on the 13th as the storm moved slowly westward. The GOES-8 visible image (fig. 2) conveys a rather weak tropical storm with mostly low level circulation to the west of the center. Most of the convection lies to the east due to shearing by an approaching upper level trough from the west. Arlene passed slightly more than 100 miles east of Bermuda on the 17th while weakening and moving slowly northward. There was no significant impact to Bermuda.

Bret - Sixty-one days had elapsed when the second tropical storm of the season formed, this time in the Bay of Campeche on August 18. Bret moved slowly northward across the western Gulf of Mexico and strengthened to a dangerous category 4 hurricane on the 22nd while approaching the South Texas coast some 70 miles east of Brownsville. A NOAA-14 satellite image (fig. 3) clearly shows a compact but powerful Bret shortly before landfall. Bret made landfall on Padre Island early evening on August 22 with sustained winds around 100 knots. Fortunately, Bret made landfall in a sparsely populated area, and its areal extent of strong winds was small. There were no deaths reported and the total damage estimate is $60 million. It is interesting to note that Bret was the first hurricane to affect South Texas since Hurricane Allen in 1980. Table 2 provides rainfall totals for stations exceeding 6.00 inches.

Table 2 - Bret Precipitation Totals in Texas (>6.00") from Selected Stations

Data from final NCDC cooperative station database for period August 22 - 24, 1999

COOP ID	STATION NAME	RAINFALL
413025	EXXON GAS PLANT	16.00
417170	PORT ARANSAS	14.50
418081	SARITA 7 E	13.18
414810	KINGSVILLE	11.16
419559	WELDER W'LIFE FOUNDATION	9.22
410805	BISHOP	9.14
413063	FALFURRIAS	8.79
412906	ENCINAL	7.70
411932	CONCEPCION 3 S	7.64
412824	EL INDIO	7.50
417677	ROBSTOWN	6.93
410787	BIG WELLS 2 W	6.66
415661	MATHIS 4 SSW	6.65
411651	CHAPMAN RANCH	6.48
412679	EAGLE PASS	6.40

Cindy - While Bret was stirring the waters in the southwestern Gulf of Mexico, Cindy formed near the Cape Verde Islands on August 19. It spent all of its time in the eastern and central North Atlantic Ocean without affecting land. Moving west to west-northwest-ward, it became a hurricane on the 26th and reached its maximum intensity of 120 kts on the 28th. The GOES-8 visible image (fig. 4) taken on August 28 shows Hurricanes Cindy and Dennis. Cindy is on the right with a very large eye relative to its overall diameter. Cindy gradually recurved across the central North Atlantic Ocean over the next several days and merged with an extra-tropical low on the 31st about 1000 miles west of the Azores.

Dennis - The hurricane season was heating up when the third major hurricane, Dennis, formed within a week of Bret and Cindy. Dennis developed over the western North Atlantic Ocean on August 24, about 225 miles east of Turks Island in the southeastern Bahamas. After strengthening to a hurricane on the 26th, Dennis produced near-hurricane conditions at Abaco Island on the 28th (fig. 4). Dennis continued to strengthen during that day and reached its peak strength of 90 knots later on the 28th. Dennis, a category 2 storm, moved up the South Carolina Coast on the 29th and early morning of the 30th, passing Cape Fear, North Carolina, before dawn with the center of the eye 60 miles offshore. Winds gusted to 97 knots at Frying Pan Tower, 35 miles offshore from Bald Head Island (Cape Fear). Along the coast, gusts were mostly in the 55 to 80 knot range...although a gust at Wrightsville Beach hit 96 knots. Figure 5 shows Dennis affecting the Carolina Outer Banks with tropical storm and possibly hurricane conditions. At this time the eye is no longer visible, a sign of weakening. Dennis was downgraded to a tropical storm on September 1, while drifting erratically, roughly 100 miles east of Cape Hatteras. Dennis moved southward and then north-westward, finally making landfall in North Carolina on September 4. Sustained winds were just below hurricane strength with winds at 60 knots. After moving inland, Dennis was absorbed by an extra-tropical low over New York State on September 8. Portions of coastal North Carolina were affected by Dennis on its initial pass-by and again at final landfall.

Although relatively minor, beach erosion was worst on Holden Beach, Brunswick County, where a teetering house fell off its pilings and a septic tank was exposed. In Wrightsville Beach, New Hanover County, a couple of power poles were snapped. Unfortunately, the hurricane approached eastern North Carolina during one of the highest astronomical tides of the month. The dune structure on Hatteras Island was breeched in numerous locations. Just north of Buxton, a 3000 foot long section of Highway 12 was completely lost. The peak storm surge was approximately 4 feet, and along the Neuse River tides were 8 to 10 feet above normal. Residents of Cedar Island in Carteret County, Ocracoke in Hyde County, and others in Pamlico County reported this was the highest water since 1933.

The greatest rainfall occurred over Carteret, southern Craven, Outer Banks Hyde, and Outer Banks Dare County. Doppler radar estimates were near 6 to 8 inches with some areas showing 8 to 10 inches and above. Table 3 lists selected stations reporting greater than 8 inches of rain for

the period August 29 through September 7. These rains helped set the stage for the disastrous flooding event from Hurricane Floyd a couple of weeks later. No tornadoes were reported and only minor fresh water flooding was reported.

No fatalities were reported in direct relationship to Hurricane Dennis, but four deaths related to high surf conditions were reported in Florida. A tornado in Hampton, Virginia, was responsible for several serious injuries. The damage estimate for North Carolina and Virginia is $157 million.

Table 3 - Dennis Precipitation Totals (>8.00") from Selected Stations

Data from final NCDC cooperative station database for period Aug 29 - Sep 7, 1999.

COOP ID	STATION NAME	RAINFALL
North Carolina		
316349	OCRACOKE	17.18
311458	HATTERAS BILLY MITCHELL AP	16.87
315830	MOREHEAD CITY 2 WNW	14.00
311606	CEDAR ISLAND	13.93
310576	BAYBORO 3 E	11.92
310375	AURORA 6 N	10.67
318113	SOUTHPORT 5 N	10.12
310674	BELHAVEN 5 SE	9.63
313638	GREENVILLE	9.48
312719	ELIZABETH CITY	9.42
319440	WILLIAMSTON 1 E	8.86
318706	TRENTON	8.85
319100	WASHINGTON 1 E	8.84
315116	LONGWOOD	8.53
316853	PLYMOUTH 5 E	8.50
Virginia		
444768	LAWRENCEVILLE 3 E	10.21
448192	SUFFOLK LAKE KILBY	8.96

Emily - On the same day Dennis was named, Emily was born about 400 miles east of the Windward Islands early on August 24. Emily moved northwest and then northward for a few days. Its center remained at least 250 miles east of the Lesser Antilles. Winds reached 45 knots late on the 24th, but further development was limited by the larger and stronger circulation of hurricane Cindy (fig. 6). Emily was absorbed by Cindy on the 28th.

Floyd - Hurricane Floyd first became a tropical depression on September 7 over the tropical Atlantic Ocean about 1000 miles east of the Lesser Antilles. The strengthening tropical cyclone moved on a general west-northwest heading for several days and reached its peak intensity of 135 knots making it a strong category 4 hurricane on September 13 while centered about 300 miles east of the central Bahamas. Figure 7 shows a well formed, symmetrical storm with a relatively large eye. The eye of Floyd moved directly over Eleuthera and Abaco Islands (fig. 8) on the 14th as the intensity of the hurricane fluctuated between categories 3 and 4. As Floyd moved through the northwest Bahama islands it began to parallel the southeast U.S. coast going toward the north-northwest and then toward the north on the 15th. Floyd passed relatively close to the entire U.S. east coast, requiring hurricane warnings from south Florida to Massachusetts. Excluding the New York City metropolitan area, which was under a Tropical Storm Warning, the last hurricane to require warnings for as large a stretch of coastline was Hurricane Donna in 1960. An estimated two million people were evacuated from Floyd's danger, probably the largest evacuation in U.S. history.

Floyd began to weaken as it passed just over 100 miles east of the Florida east coast. The hurricane made landfall very early on the 16th near Cape Fear, North Carolina, with category 2 winds of 90 knots (fig. 9). The University of Oklahoma Doppler-On-Wheels team, positioned at Topsail Beach, North Carolina, recorded sustained winds of 83 knots with gusts to 106 knots at about 0300 LST. The peak inland wind gust report was 71 knots at Cherry Point Marine Corp Air Station. The peak offshore report was 83 knots at Duck Pier. The peak storm surge was approximately 10 feet.

The eye moved north-northeast over the towns of Jacksonville, New Bern, Washington, and Plymouth, and continued over the eastern shores of Virginia. Floyd weakened rapidly over land and lost its tropical characteristics early on the 17th. Its center moved offshore along the coasts of the Delmarva Peninsula and New Jersey, and then it moved over Long Island and New England on the 17th when it became extra-tropical.

Rainfall totals from Floyd were very excessive. These rains, combined with saturated ground water levels from previous rain events, including Hurricane Dennis, produced a flood disaster of major proportion, especially over the eastern third of North Carolina. Rainfall totals were as high as 15 to over 20 inches over portions of eastern North Carolina and Virginia, 12 to 14 inches over portions of Maryland, Delaware, and New Jersey, 4 to 7 inches over eastern Pennsylvania and southeastern New York, and up to 11 inches over portions of New England. Table 4 lists selected stations reporting greater than 10 inches of rain for the period September 14 through September 17. The combined rainfall from Dennis and Floyd exceeded 30 inches in some areas, with Southport, North Carolina, receiving over 34 inches.

Extreme flooding was experienced across most counties. Inland flooding exceeded Hurricanes Bertha, Fran, Bonnie, and Dennis combined. Most counties reported their worst flooding on record. The Tar River in Greenville and the Neuse River in Kinston were nearly 15 feet above their flood stages of 13 and 14 feet, respectively. The Tar River remained above flood stage for

nearly two weeks while the Neuse River remained above flood stage for over a month. The Northeast Cape Fear River in Chinquapin was 8 to 10 feet above the flood stage of 13 feet. Figure 10 shows a dramatic comparison of eastern North Carolina before and after Floyd taken by NOAA-15. Rivers not normally visible stand out quite clearly in the later 1 km resolution image. Record-setting floods occurred at 19 river gauge locations in North Carolina, Virginia, New Jersey, Delaware, and Pennsylvania, with the Tar River Gauge in North Carolina exceeding the previous record by as much as 10 feet. The National Weather Service's June 2000 assessment report, *Hurricane Floyd Floods of September 1999*, states that a 500-year flood (.002 probability) occurred at Tarboro, Rocky Mount, and Enfield, North Carolina.

In addition to one person killed in the Bahamas, there were 56 directly-related deaths in the United States, 48 of those due to drowning from fresh water flooding. This makes Floyd the deadliest U.S. hurricane since Agnes of 1972. Total damage estimates range from $4.5 to over $6 billion. North Carolina had over 7000 homes destroyed, 56,000 homes damaged, 1500 people rescued, and over 500,000 customers without electricity.

Table 4 - Floyd Precipitation Totals (>10.00") from Selected Stations

Data from final NCDC cooperative station database for the period September 14-17, 1999

COOP ID	STATION NAME	RAINFALL
Delaware		
073595	GREENWOOD 2 NE	10.58
Maryland		
181750	CHESTERTOWN	12.59
185985	MILLINGTON 1 SE	11.77
180193	ANNAPOLIS POLICE BRKS	10.42
New Jersey		
281335	CANOE BROOK	10.02
284887	LITTLE FALLS	14.13
North Carolina		
318113	SOUTHPORT 5 N	24.06
319467	WILMINGTON 7 N	19.26
319457	WILMINGTON INTERNATIONAL ARPT	19.06
314962	LEWISTON	18.13
317400	ROCKY MOUNT 8 ESE	18.00
315116	LONGWOOD	16.54

319440	WILLIAMSTON 1 E	16.28
318060	SNOW HILL	16.12
319100	WASHINGTON 1 E	15.48
319081	WARSAW 5 E	15.45
318706	TRENTON	15.13
319354	WHITESVILLE 5 S	15.07
313638	GREENVILLE	14.24
312732	ELIZABETHTOWN LOCK 2	14.21
317395	ROCKY MOUNT 6 SW	14.08
317725	SCOTLAND NECK #2	13.99
314456	JACKSON	13.88
314689	KINSTON AG RESEARCH	13.74
319423	WILLARD 4 SW	13.23
314684	KINSTON 5 SE	13.20
317319	ROANOKE RAPIDS	12.91
313510	GOLDSBORO SEYMOUR JOHNSON AFB	12.70
319357	WHITEVILLE 7 NW	12.00
312827	ENFIELD	11.84
311881	CLINTON 2 NE	11.50
319476	WILSON 3 SW	10.73

South Carolina

386153	MYRTLE BEACH 2	16.80
381093	BROOKGREEN GARDENS	14.71
385306	LORIS 1 S	14.18
383468	GEORGETOWN 2 E	13.84
381997	CONWAY	13.05

Vermont

435416	MOUNT MANSFIELD	11.53

Virginia

449151	WILLIAMSBURG 2 N	16.98
444044	HOLLAND 1 E	15.19
448800	WAKEFIELD 1 NW	12.81
449025	WEST POINT 2 NW	12.35
448192	SUFFOLK LAKE KILBY	10.94
445338	MATHEWS 6 SE	10.35

Gert - The fourth category 4 hurricane formed several days after Floyd on September 11 in the far eastern tropical Atlantic Ocean. Moving to the west-northwest, it became a tropical storm on the 12th and a hurricane on the 13th. Gert strengthened to a 130 knot hurricane on the 16th, while located about 575 miles east of the Leeward Islands (fig.11). While beginning a gradual weakening process, Gert recurved northward over the next several days as it moved across the

central North Atlantic. The center passed about 130 miles east of Bermuda on the 21st giving Bermuda sustained winds of 65-70 knots for a brief time. Gert tracked near southeastern Newfoundland on the 23rd, where gale-force winds were experienced. It became extra-tropical soon after.

Harvey - Tropical Storm Harvey formed in the Gulf of Mexico from a tropical wave. It became a tropical depression on September 19 over the central Gulf and moved toward the east-northeast. In spite of unfavorable winds aloft, Harvey strengthened and became a 50 knot tropical storm while centered about 250 miles west-southwest of Tampa, Florida (fig.12). Taking an abrupt turn toward the southeast, Harvey moved inland on the southwest Florida coast on the 21st and produced tropical storm winds over portions of the Florida Keys and extreme south Florida. Harvey was absorbed by a frontal system on the 22nd just east of south Florida.

Irene - After a little over three weeks of no tropical storm activity in the Atlantic, Hurricane Irene formed from a broad area of low pressure in the southwest Caribbean Sea on October 13. It became a tropical storm on the same day and moved northward across western Cuba on the 14th with 60 knot winds. Irene strengthened into a minimal hurricane on the 15th and moved northeastward across south Florida where Irene dumped 10 to 20 inches of rain along its path. Considerable fresh-water flooding resulted.

Rainfall totals in southeast Florida ranged from 6 to 17 inches with many areas getting 10 to 15 inches (See table 5). The greatest reliable amount reported was 17.45 inches at Boynton Beach, Florida. The highest sustained wind over land was 50 knots at Miami Beach with many readings from 35 to 45 knots. Fowey Rocks Light reported sustained winds of 57 knots while the Miami NWS Doppler radar estimated areas of sustained hurricane force winds in the Atlantic Ocean just off the southeast Florida coast. Among the highest recorded gusts were readings of 81 knots near Belle Glade, 74 knots at Homestead Air Reserve Base, 73 knots at Fowey Rocks Light, 64 knots at Turkey Point nuclear power plant and 61 knots at Miami International Airport. The lowest barometric pressure on the south Florida peninsula was 989.9 mb at Opa Locka Airport. Storm surge and beach erosion were minimal.

Table 5 - Irene Precipitation Totals in Florida (>7.00") from Selected Stations

Data from final NCDC cooperative station database for the period October 14-15, 1999.

COOPID	STATION NAME	RAINFALL
085667	MIAMI NWSFO	14.31
083163	FORT LAUDERDALE	14.08
087020	PERRINE 4 W	13.76
083909	HIALEAH	13.52
083168	FORT LAUDERDALE BEACH	12.37
084095	HOMESTEAD GEN AVIATION	12.02
087760	ROYAL PALM RANGER STN	11.78

088780	TAMIAMI TRAIL 40 MI BEND	10.91
089525	WEST PALM BEACH INTL ARPT	10.82
085663	MIAMI INTL AP	10.30
085184	LOXAHATCHEE NWR	10.20
088620	STUART 1 S	9.87
081858	CORAL SPRINGS	9.82
088841	TAVERNIER	9.82
081306	CAPE FLORIDA	9.39
084320	ISLAMORADA	8.99
084570	KEY WEST INTL ARPT	8.64
086406	OASIS RANGER STN	8.45
082441	DUCK KEY	7.74
087254	POMPANO BEACH	7.72
089219	VERO BEACH 4 W	7.68
083207	FORT PIERCE	7.50
085658	MIAMI BEACH	7.41

Four tornadoes touched down in Broward and Palm Beach counties, injuring three persons. Several other areas of localized wind damage were reported, especially near the southeast shore of Lake Okeechobee, and were likely attributable to convective downbursts.

There were no direct deaths from Irene, but eight persons died in the aftermath. Five persons were electrocuted by downed power lines, including three persons from one family. Three other persons drowned in vehicle-related accidents. Damage in southeast Florida, mainly from flooding, is estimated near $800 million which includes $335 million in agricultural losses.

Irene moved offshore over the Atlantic side of Florida on the 16th (fig.13) curving northward toward the Carolinas, but it turned northeastward on the 17th, just brushing the Outer Banks of North Carolina with Tropical Storm Force winds on the 18th. At this point the warm Gulf Stream helped Irene intensify rapidly to 95 knots. It also dropped five to ten inches of rain across portions of South and North Carolina. Continuing northeastward, Irene was absorbed by an extra-tropical low near Newfoundland. The combined system became an intense extra-tropical storm over the far North Atlantic Ocean.

Jose - Hurricane Jose developed from a tropical depression that formed about 700 miles east of the Windward Islands on October 17. As the system moved west-northwestward to northwestward it quickly became a tropical storm and then a hurricane on the 19th when it was located 150 miles east of the Leeward Islands. Jose moved over the northern Leeward Islands on the 20th (fig.14) and very early on the 21st with the center passing over Antigua and near St. Maarten. Its maximum winds reached 85 knots. Sustained winds of 70 and 65 knots were reported from Antigua and St. Maarten, respectively. Jose weakened to a tropical storm and moved across the British Virgin Islands on the morning of the 21st. After passing within 50 miles northeast of the eastern tip of Puerto Rico, the storm turned north-northeastward and moved across the central North Atlantic for the next several days. It briefly re-attained hurricane status on the 24th while passing some 300 miles east of Bermuda. Jose lost tropical characteristics on

the 25th several hundred miles south of Newfoundland.

Katrina - An uneventful and short-lived tropical storm, Katrina, formed in the southwest Caribbean Sea within a broad area of low pressure and became a tropical depression on October 28. Its winds briefly reached minimal tropical storm strength late on the 29th as it moved slowly northwestward and crossed the coast of Nicaragua near Puerto Cabezas (fig.15). For the remainder of its four days of existence, Katrina was a tropical depression moving on a generally northwestward track across Nicaragua, Honduras, and the Yucatan Peninsula. The depression dissipated on November 1, as it was absorbed by a cold front just north of the Yucatan Peninsula. Although there were no reports of damage or death, it is estimated that 10 to 15 inches of rain fell over portions of Central America.

Lenny - The hurricane season ended strongly when the fifth category 4 hurricane was born. Hurricane Lenny formed over the northwestern Caribbean Sea within a broad trough of low pressure. After several days of slow organizing and aimless drifting, the originating area of disturbed weather became a tropical depression on November 13th, not far from the Cayman Islands. Moving slowly southward and then southeastward, Lenny became a tropical storm on the 14th, centered about 175 miles southeast of Jamaica. Lenny moved mostly eastward across the central Caribbean on the 15th and 16th and reached hurricane strength on the 15th about 140 miles south of Jamaica. It then turned northeastward and reached peak intensity of 135 knots on the 17th while passing just south of St.Croix in the U.S. Virgin Islands (fig.16). Lenny was gradually weakening when its center passed very slowly over St. Maarten on the 17th. Moving southeastward and away from the Leeward Islands, Lenny weakened to a tropical storm on the 20th. Its forward motion turned again toward the northeast and then eastward, finally dissipating on the 23rd about 625 miles east of the Leeward Islands.

The U.S. Virgin Islands likely experienced category 2 hurricane conditions with winds of 85 to 95 knots. The British Virgin Islands received tropical storm conditions. Category 1 hurricane winds were measured at St. Maarten and it is likely that category 2 wind speeds occurred at this location. Other islands affected by Lenny include Anguilla, Barbuda, St. Kitts, Nevis, and Monserrat. For many locations, heavy rains over several days were the primary impact of Lenny. The approach from the west caused unprecedented wave and storm surge damage to westward-facing harbors.

There was one significant tropical depression during 1999, Tropical Depression 11. This poorly organized system contributed to widespread and prolonged heavy rains over several days in early October over the Mexican states of Puebla, Tabasco, and Veracruz. Press reports indicate that the resultant flooding was responsible for about 400 deaths, although it is unknown how many of these casualties were a direct result of the depression.

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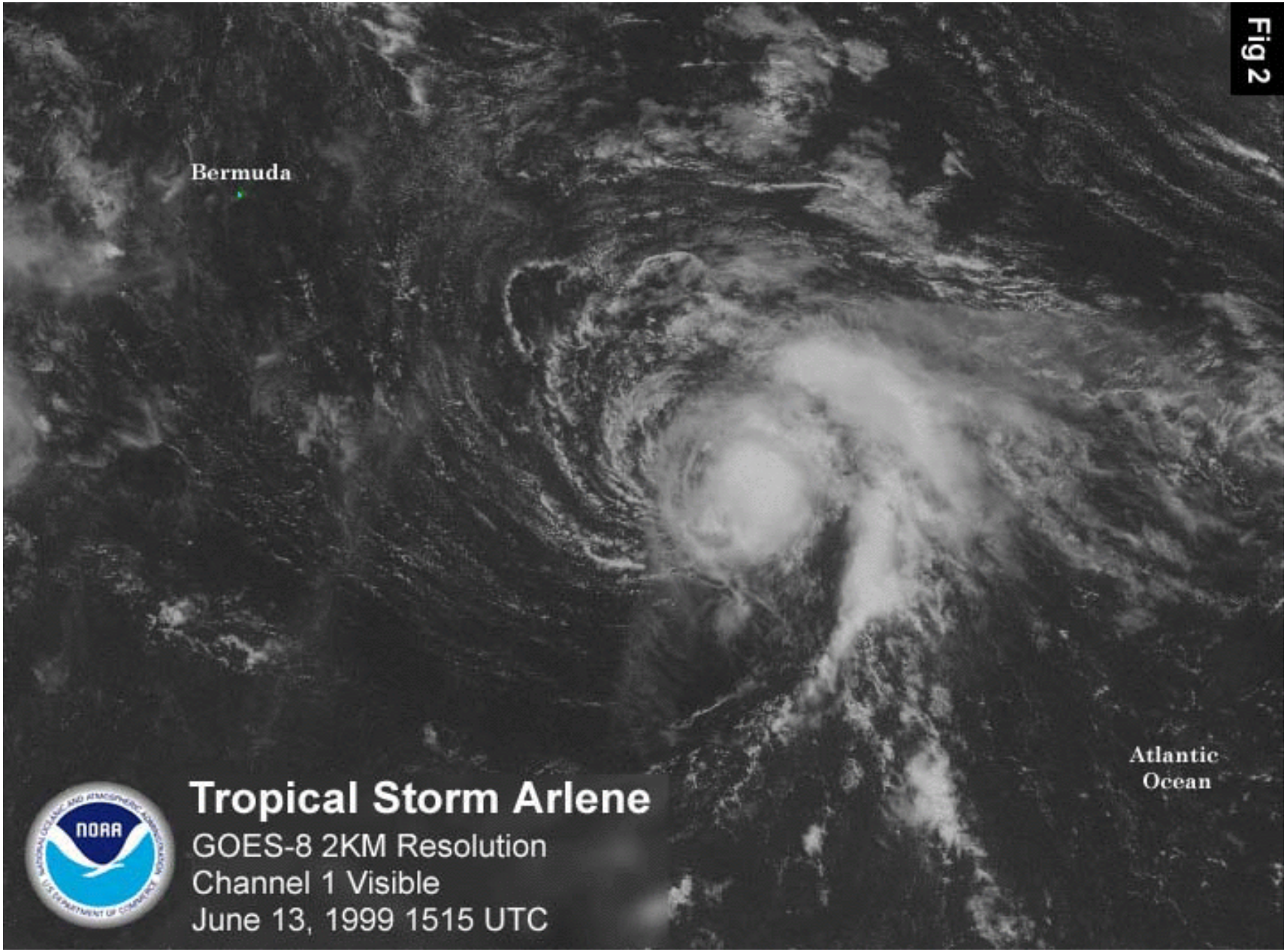
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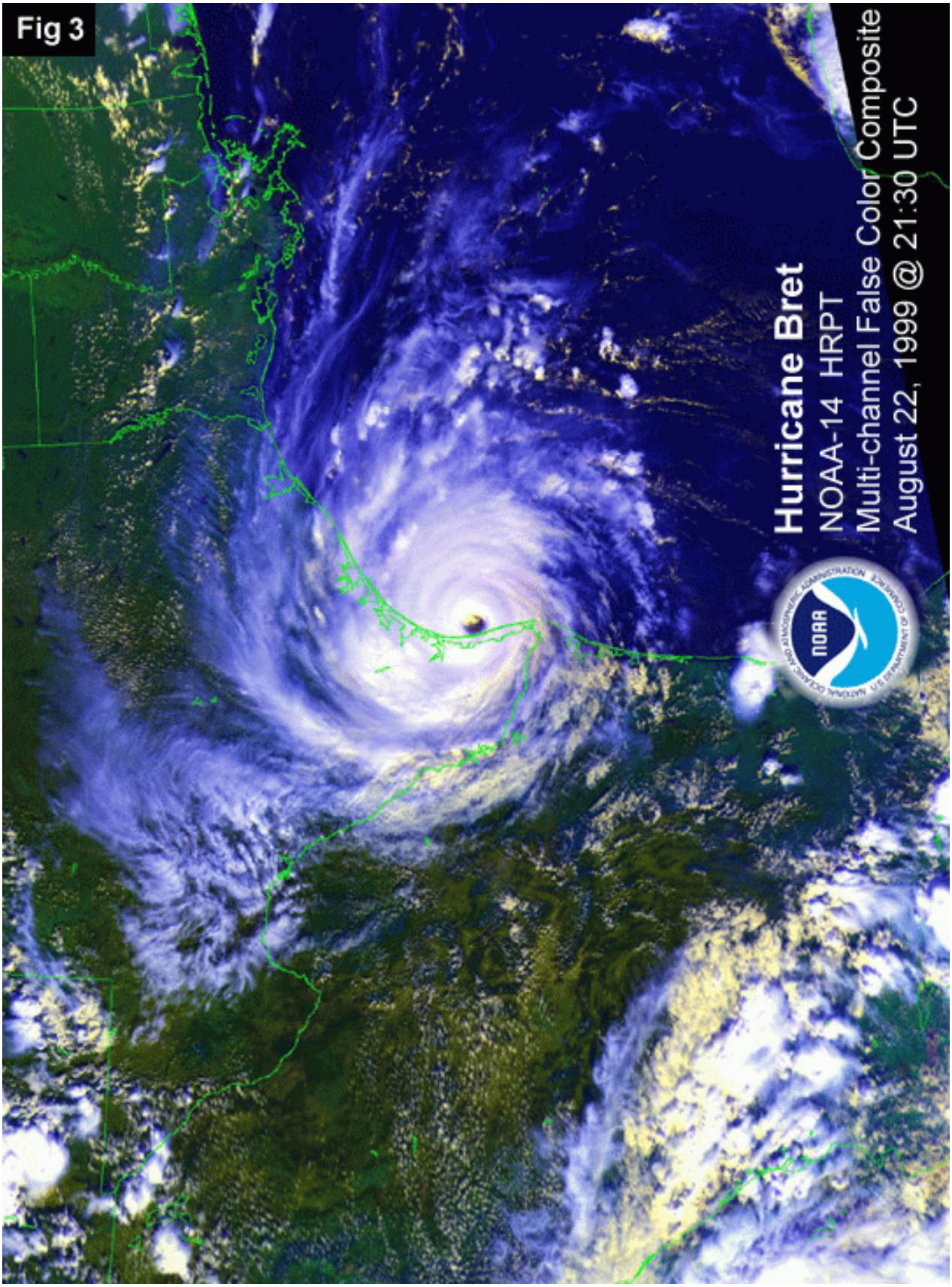
Tropical Storm Arlene
GOES-8 2KM Resolution
Channel 1 Visible
June 13, 1999 1515 UTC
NOAA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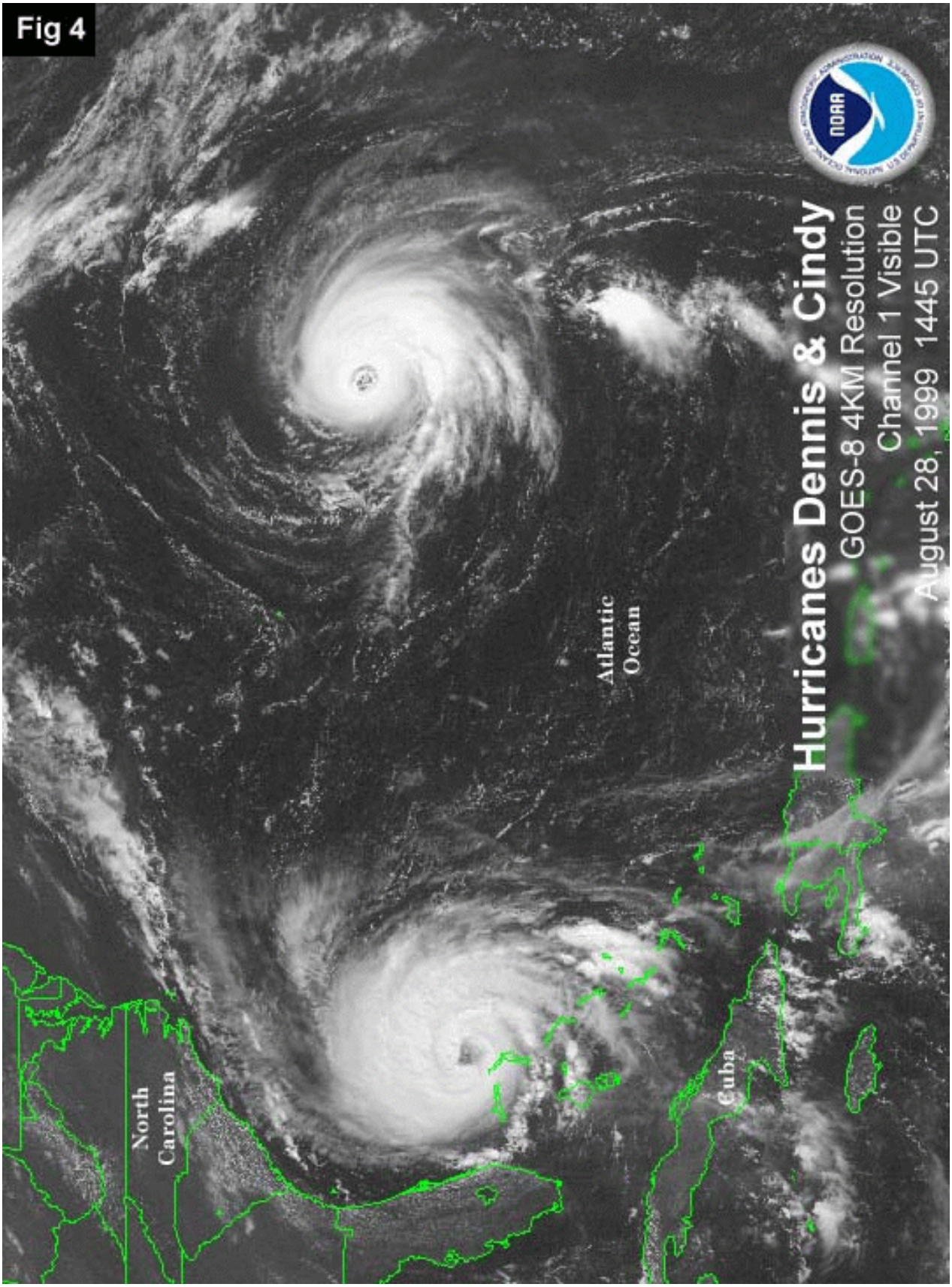
Hurricane Bret
NOAA-14 HRPT
Multi-channel False Color Composite
August 22, 1999 @ 21:30 UTC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August 28, 1999 1445 UTC
Atlantic Ocean
North Carolina
Cuba

Fig 5
Hurricane Dennis
NOAA-14 1 km AVHRR HRPT
Multi-spectral False Color Image
August 30, 1999 @ 1957 UTC
VA
NC
SC

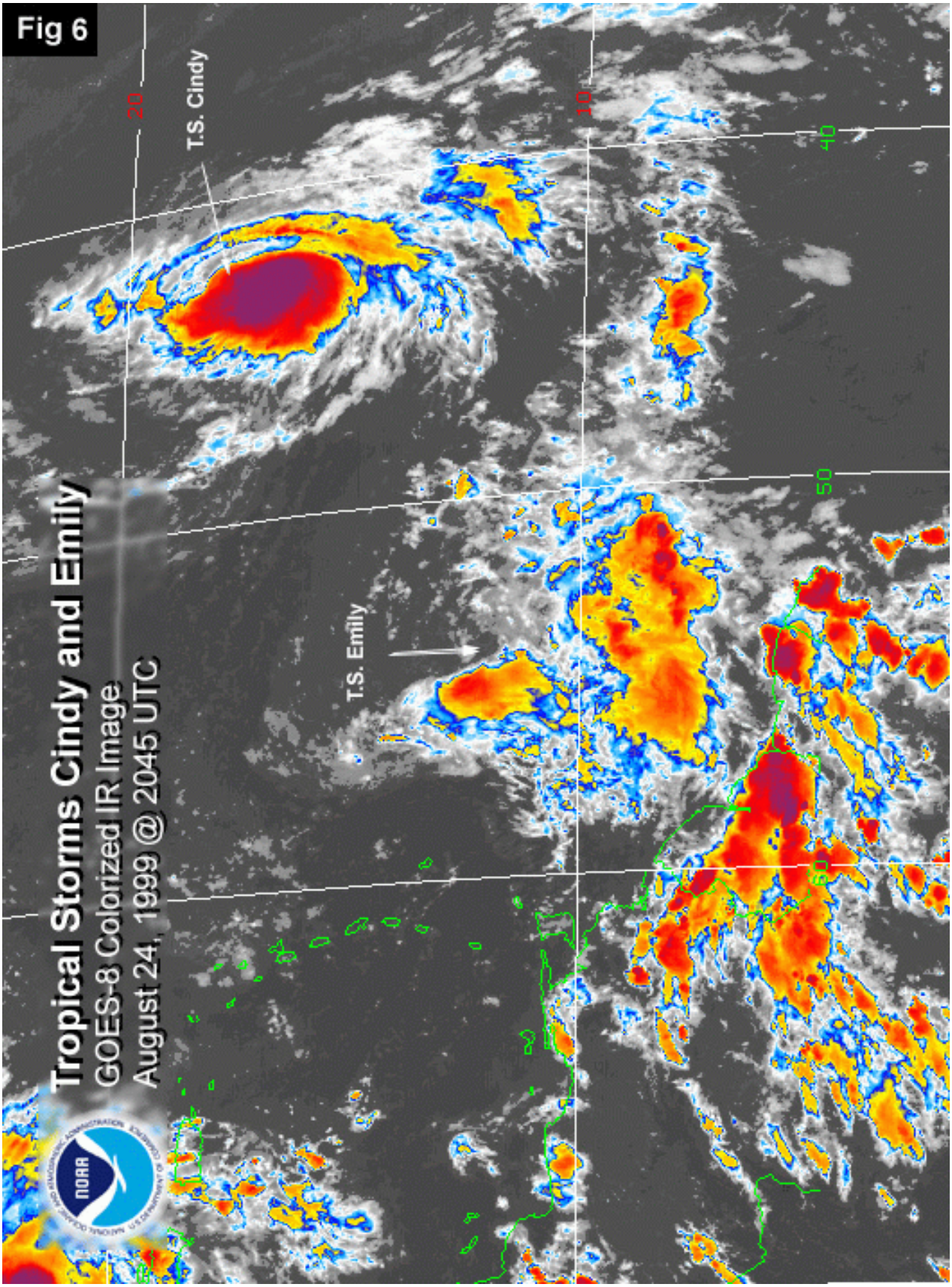


Fig 6
Tropical Storms Cindy and Emily
GOES-8 Colorized IR Image
August 24, 1999 @ 2045 UTC
T.S. Cindy
T.S. Emily
20
10
40
50
60
NOAA

Fig 7
Hurricane Floyd
NOAA-14 AVHRR HRPT
Multi-spectral False Color Image
September 13, 1999 @ 2040 UTC

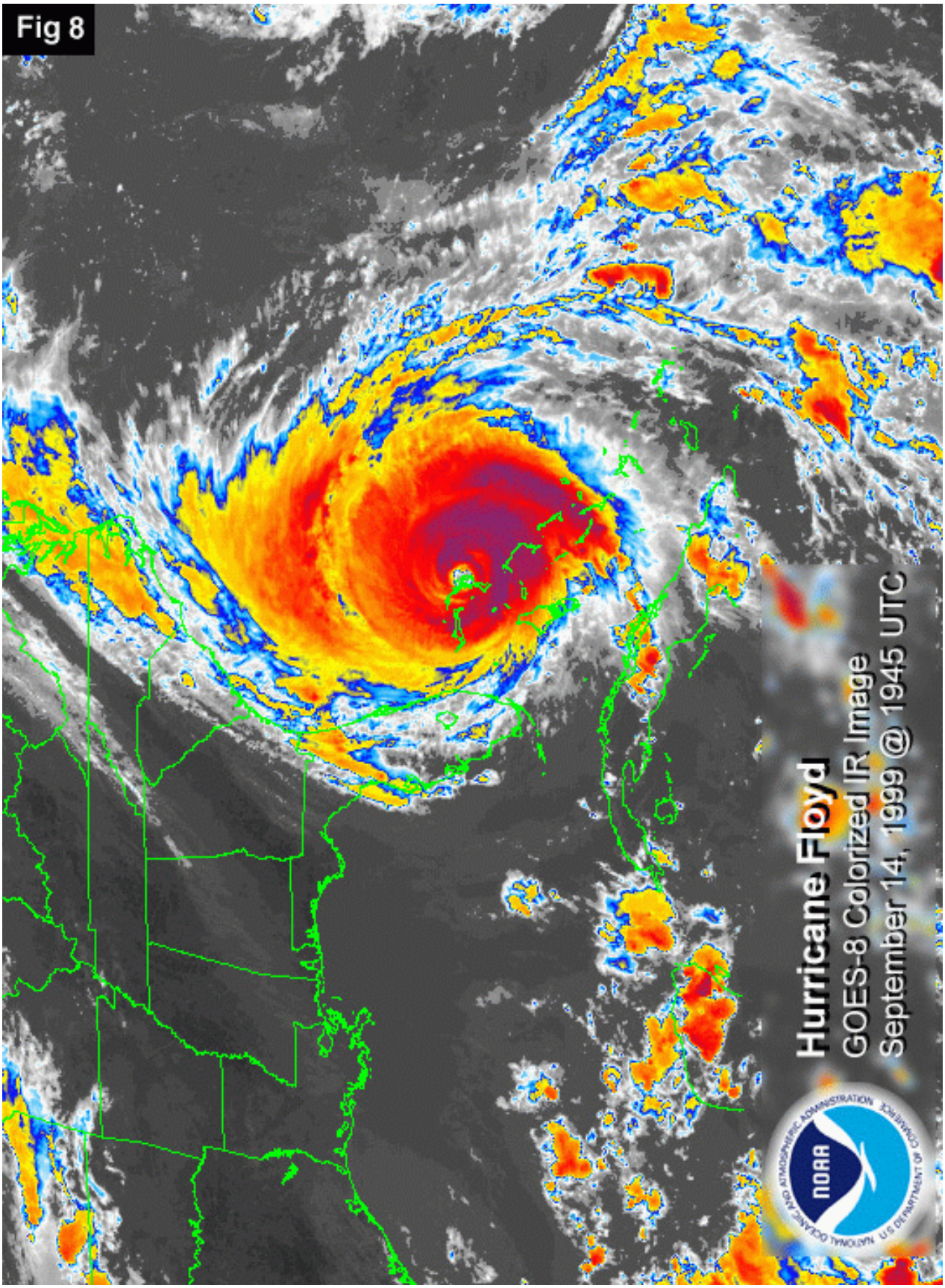


Fig 8
Hurricane Floyd
GOES-8 Colorized IR Image
September 14, 1999 @ 1945 UTC
NOAA

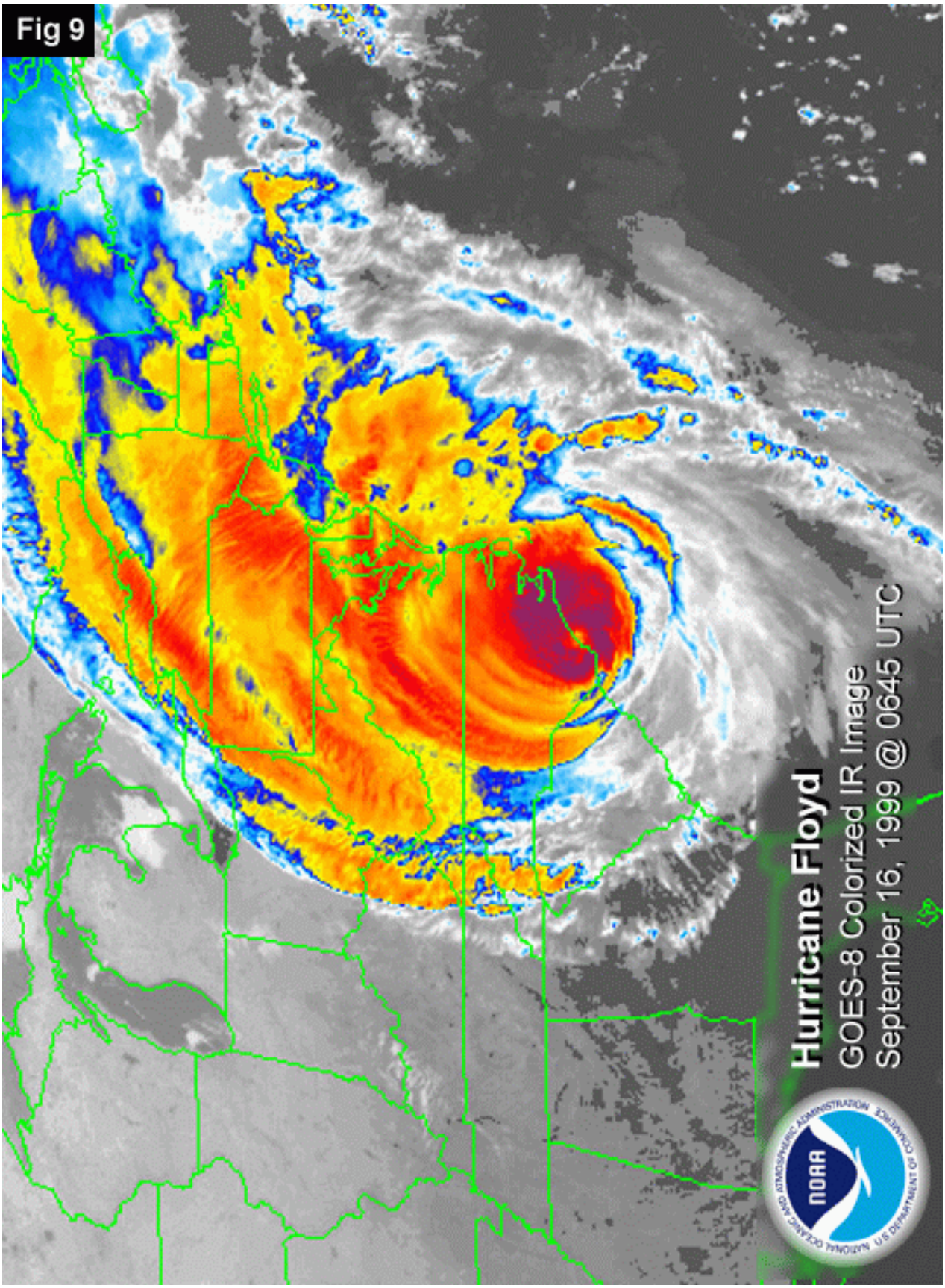
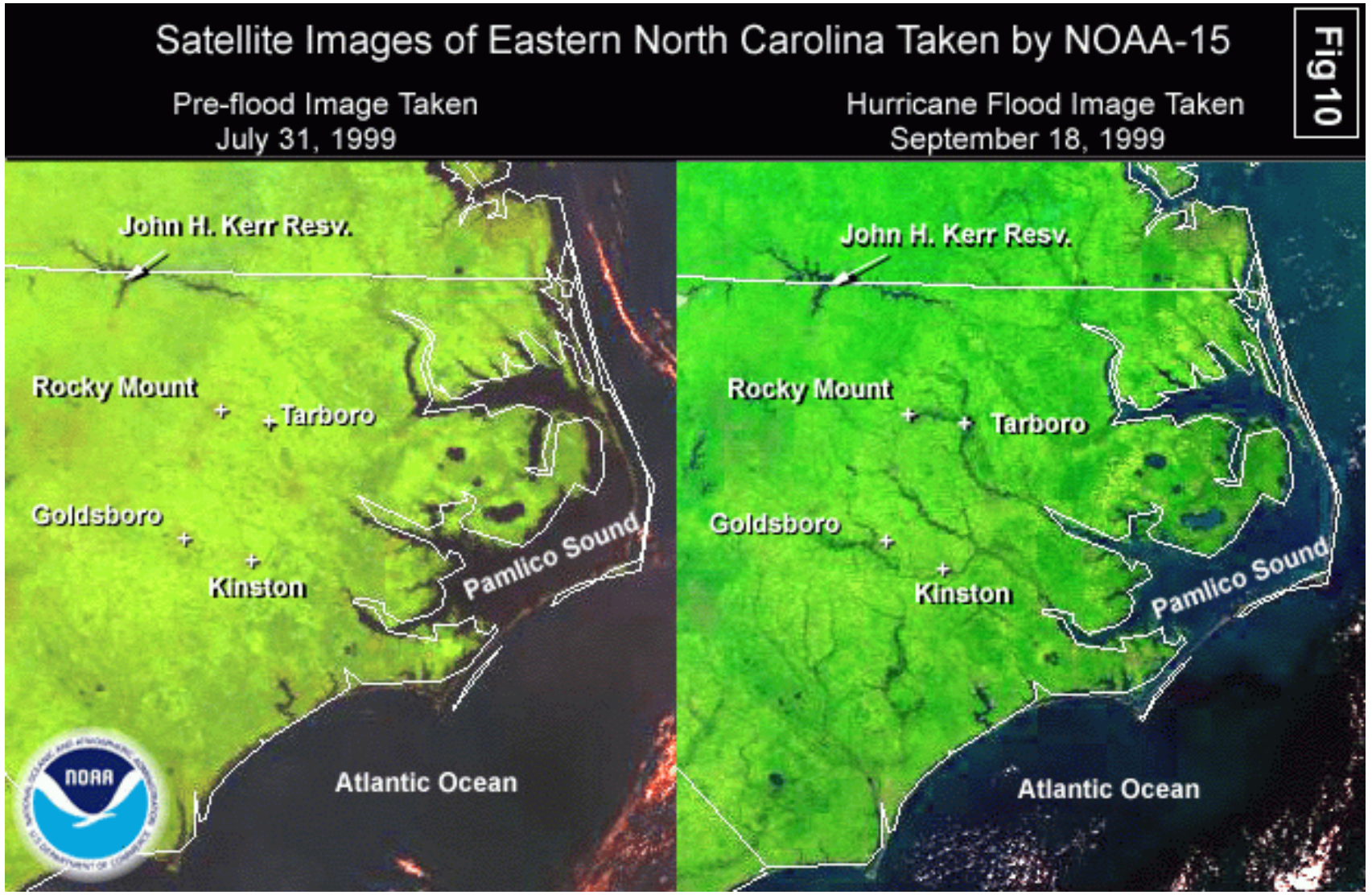


Fig 9
Hurricane Floyd
GOES-8 Colorized IR Image
September 16, 1999 @ 0645 UTC
NOAA


Satellite Images of Eastern North Carolina Taken by NOAA-15
Fig 10
Pre-flood Image Taken
July 31, 1999
Hurricane Flood Image Taken
September 18, 1999
John H. Kerr Resv.
Rocky Mount
Tarboro
Goldsboro
Kinston
Pamlico Sound
Atlantic Ocean
NOAA
John H. Kerr Resv.
Rocky Mount
Tarboro
Goldsboro
Kinston
Pamlico Sound
Atlantic Ocean

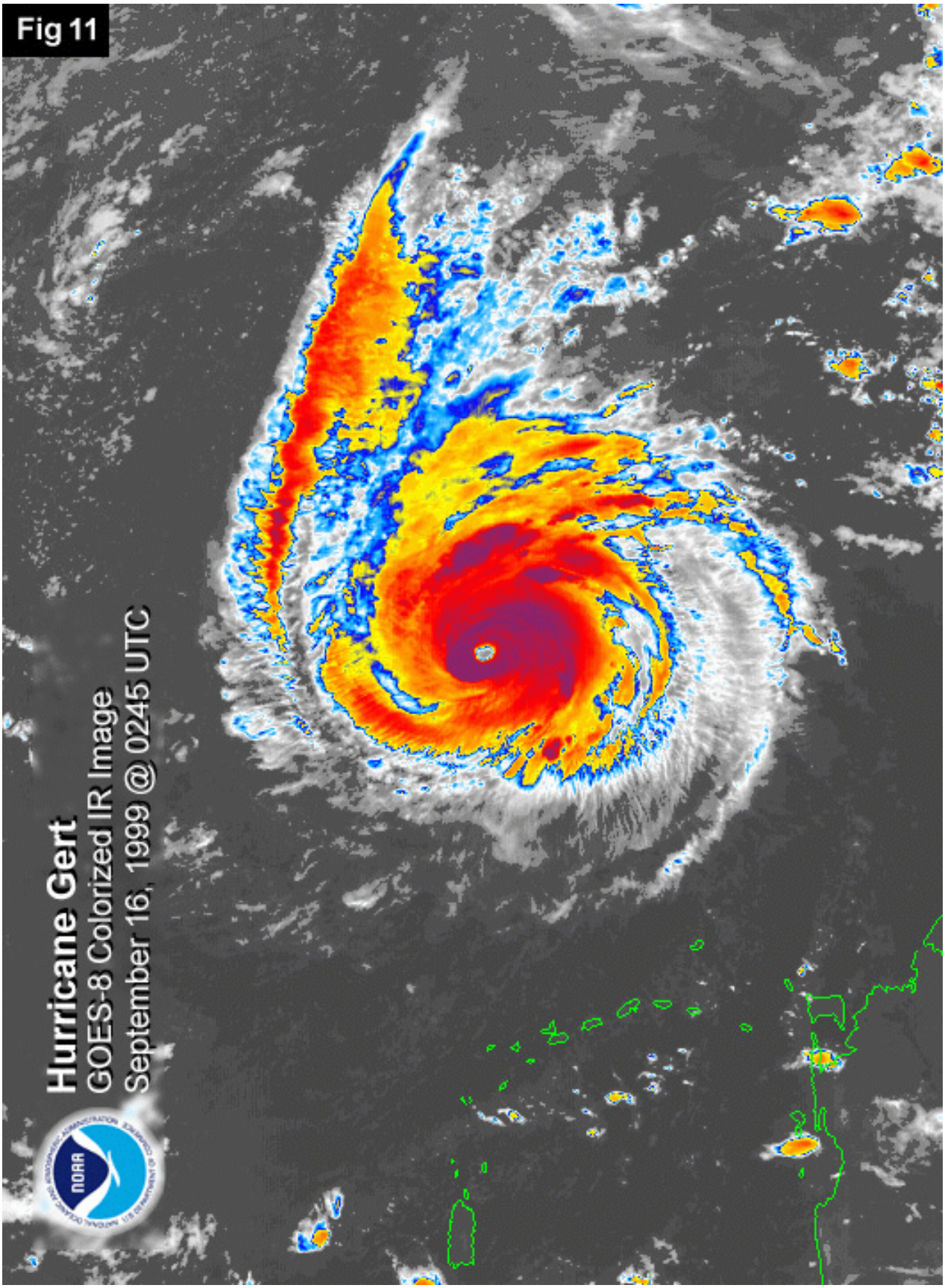


Fig 11
Hurricane Gert
GOES-8 Colorized IR Image
September 16, 1999 @ 0245 UTC

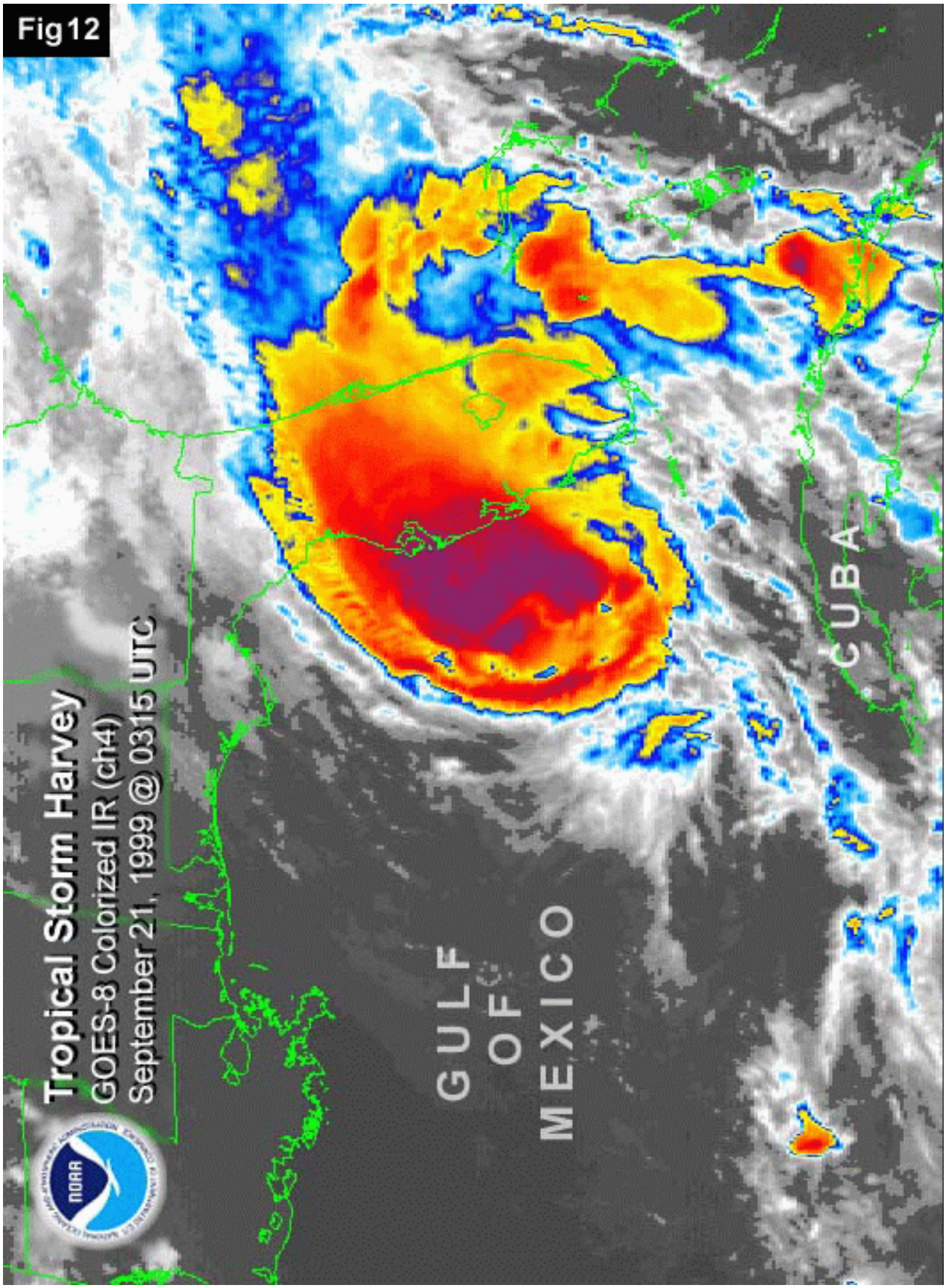


Fig12
Tropical Storm Harvey
GOES-8 Colorized IR (ch4)
September 21, 1999 @ 0315 UTC
GULF
OF
MEXICO
CUBA

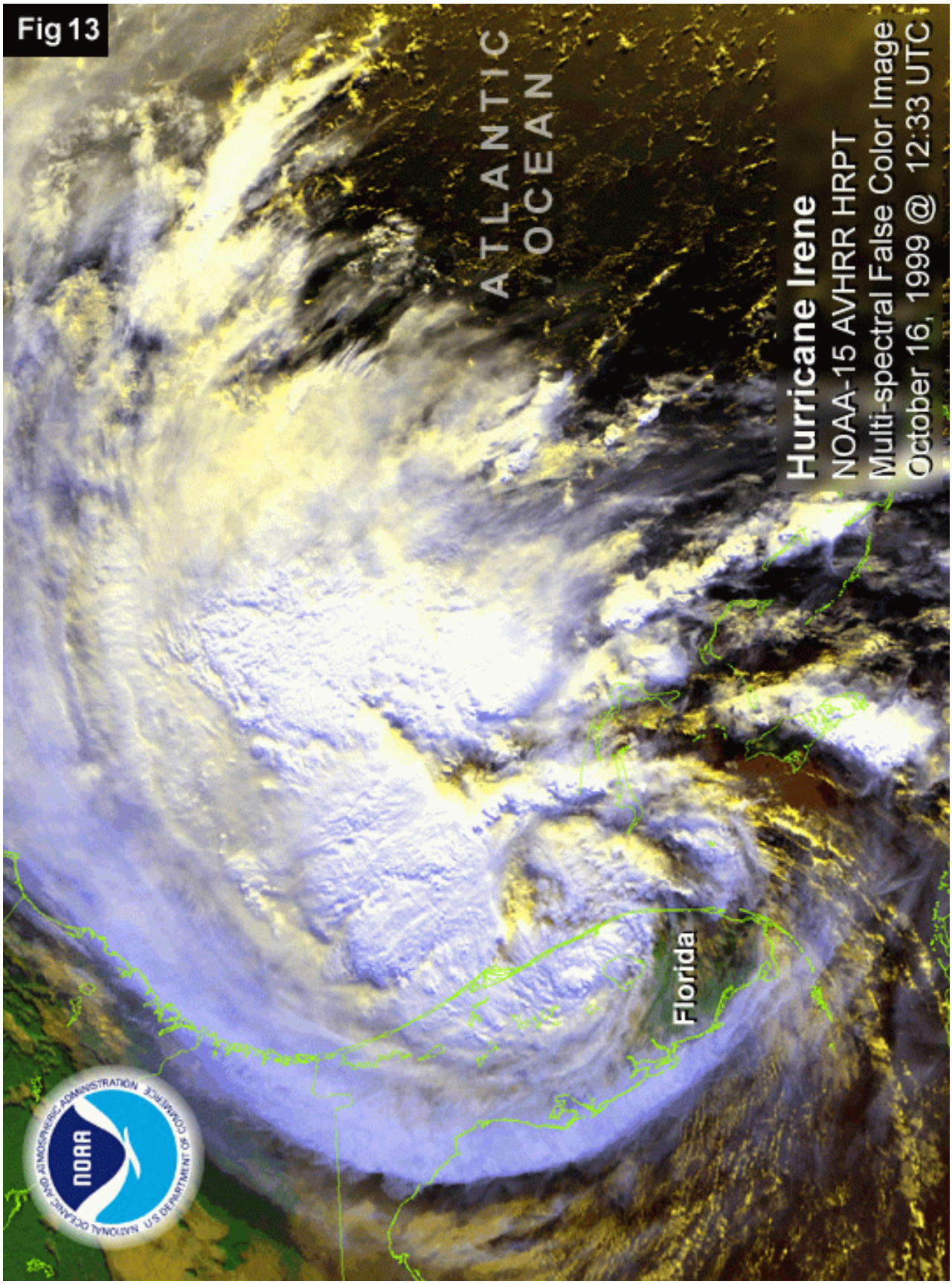


Fig 13
ATLANTIC OCEAN
Hurricane Irene
NOAA-15 AVHRR HRPT
Multi-spectral False Color Image
October 16, 1999 @ 12:33 UTC
Florida
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

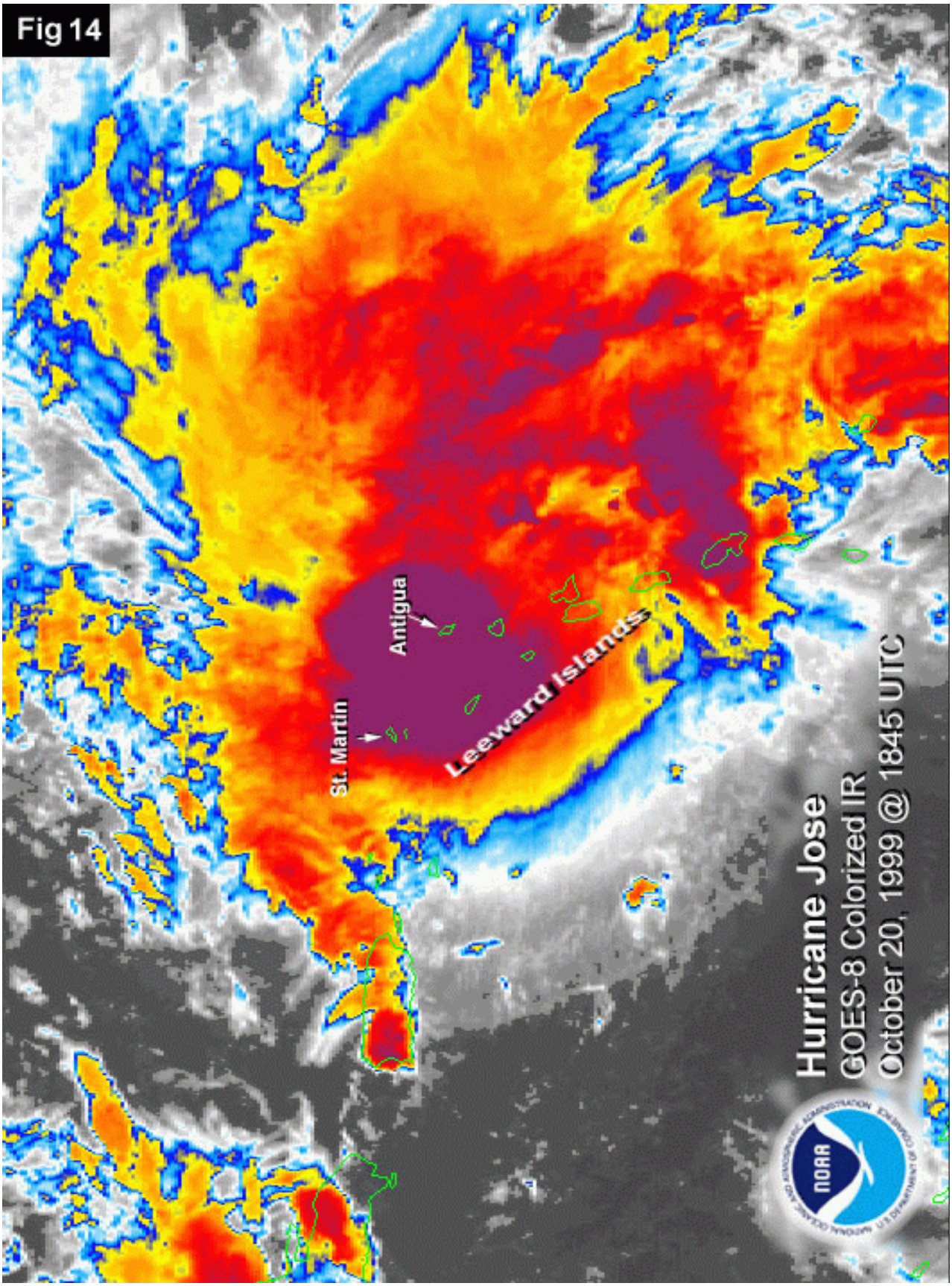


Fig 14
Antigua
St. Martin
Leeward Islands
Hurricane Jose
GOES-8 Colorized IR
October 20, 1999 @ 1845 UTC
NOAA

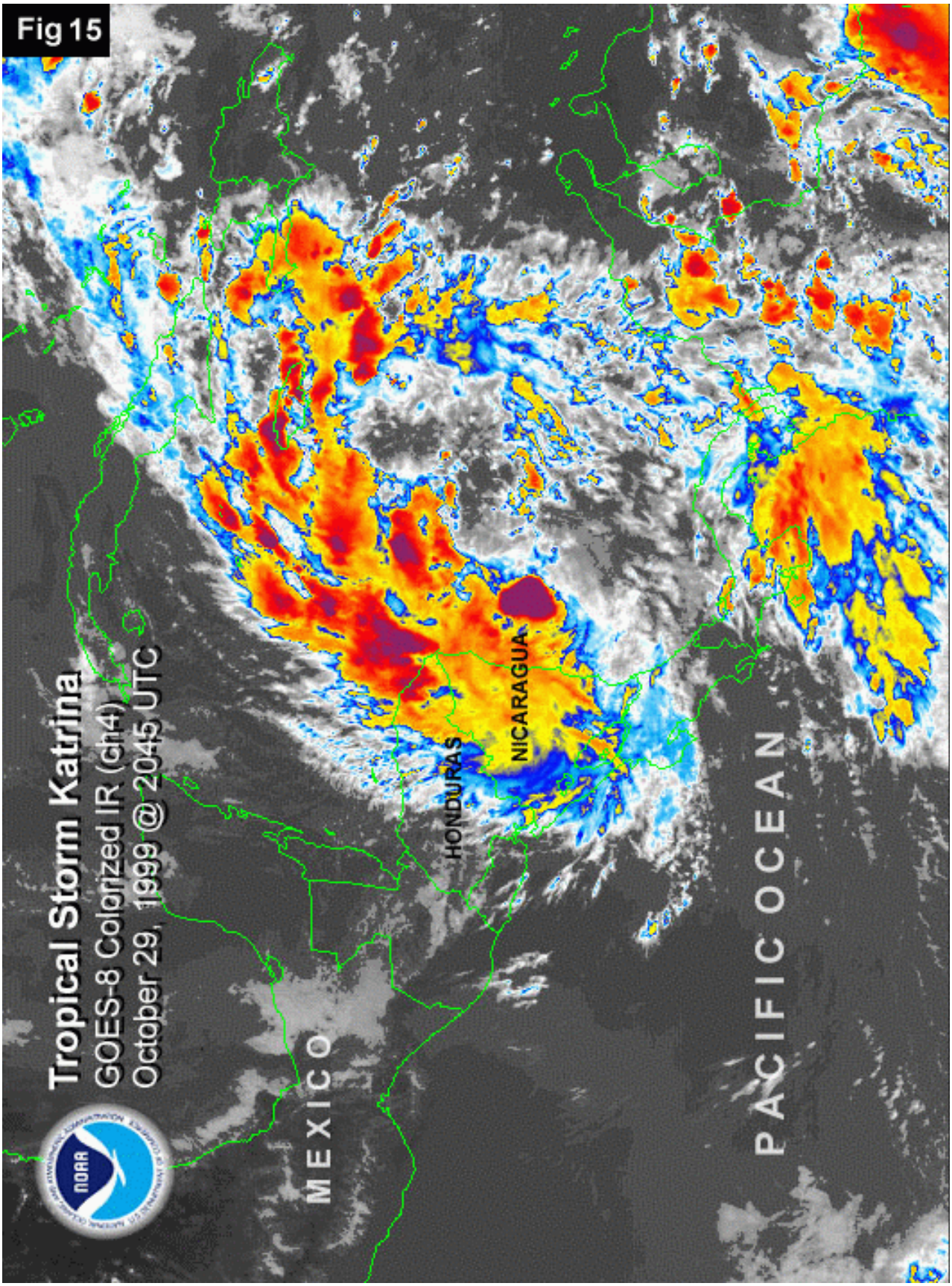


Fig 15
Tropical Storm Katrina
GOES-8 Colorized IR (Ch4)
October 29, 1999 @ 2045 UTC
MEXICO
HONDURAS
NICARAGUA
PACIFIC OCEAN

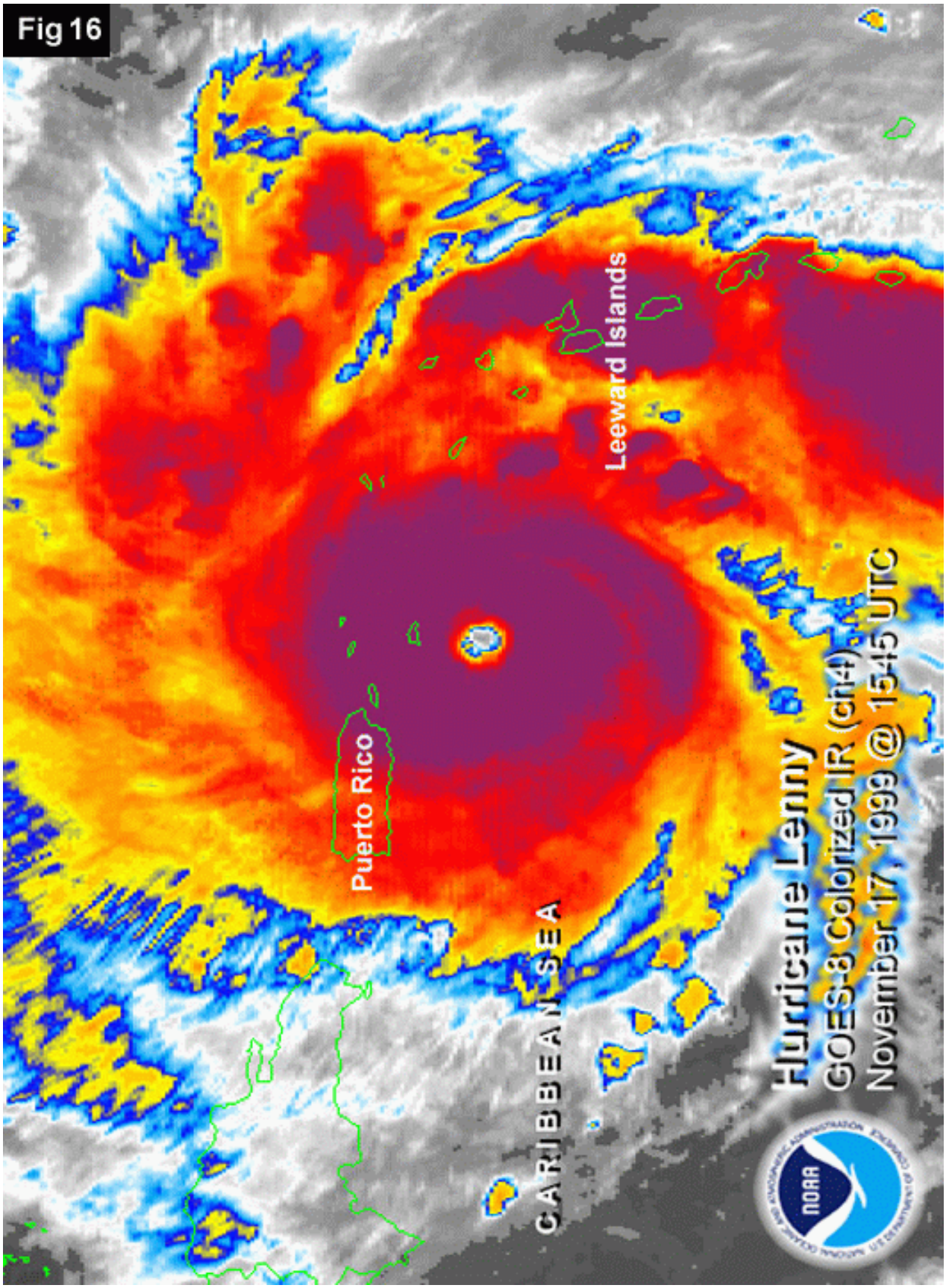
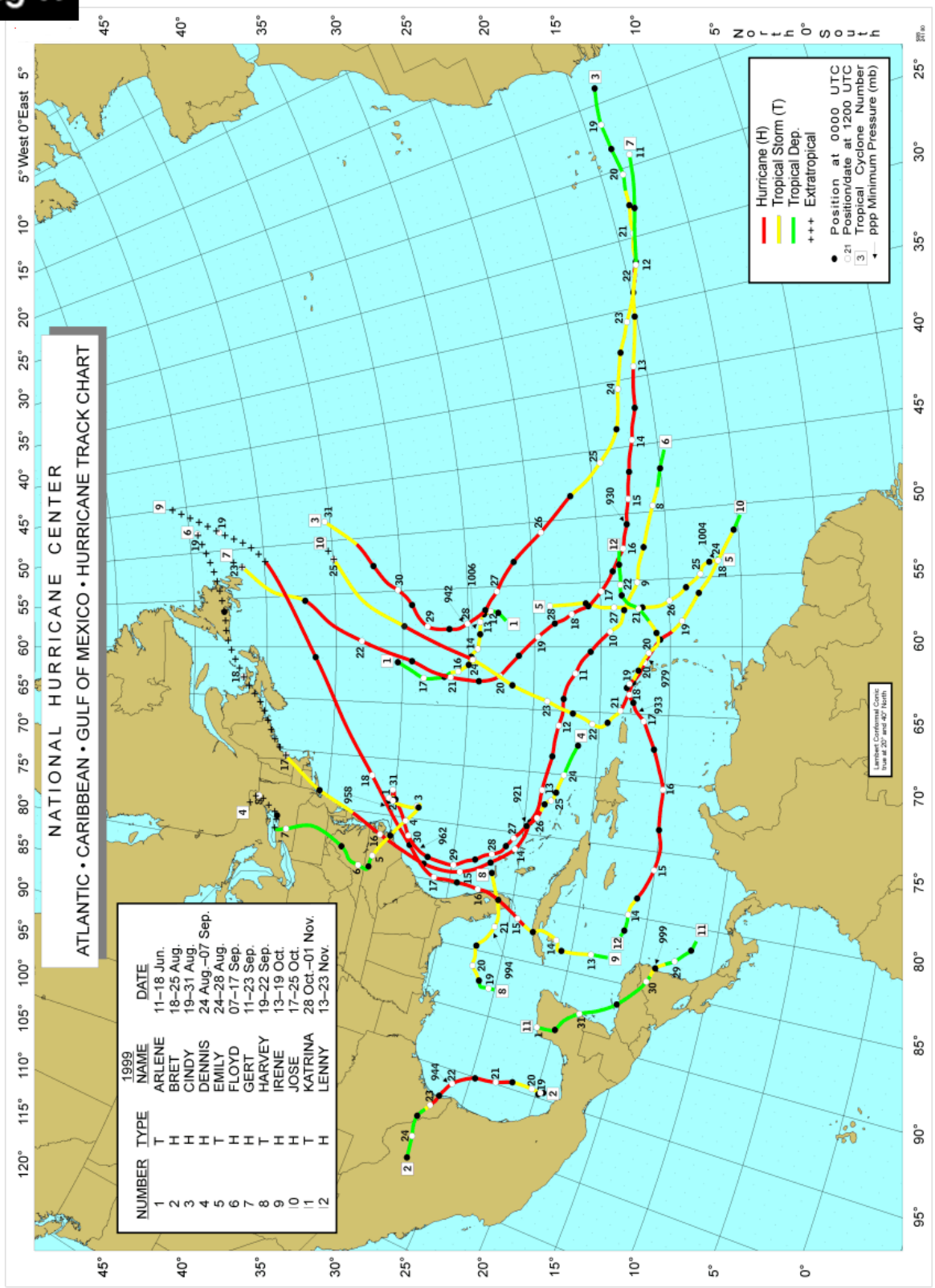


Fig 16
Puerto Rico
CARIBBEAN SEA
Leeward Islands
Hurricane Lenny
GOES-8 Colorized IR (ch4)
November 17, 1999 @ 1545 UTC
NOAA

Fig 17


NATIONAL HURRICANE CENTER
ATLANTIC • CARIBBEAN • GULF OF MEXICO • HURRICANE TRACK CHART
1999
NUMBER TYPE NAME DATE
1 T ARLENE 11–18 Jun.
2 H BRET 18–25 Aug.
3 H CINDY 19–31 Aug.
4 H DENNIS 24 Aug.–07 Sep.
5 T EMILY 24–28 Aug.
6 H FLOYD 07–17 Sep.
7 H GERT 11–23 Sep.
8 T HARVEY 19–22 Sep.
9 H IRENE 13–19 Oct.
10 H JOSE 17–25 Oct.
11 T KATRINA 28 Oct.–01 Nov.
12 H LENNY 13–23 Nov.
Hurricane (H)
Tropical Storm (T)
Tropical Dep.
Extratropical
Position at 0000 UTC
Position/date at 1200 UTC
Tropical Cyclone Number
ppp Minimum Pressure (mb)
Lambert Conformal Conic true at 20° and 40° North
North
South
5° West 0° East 5°