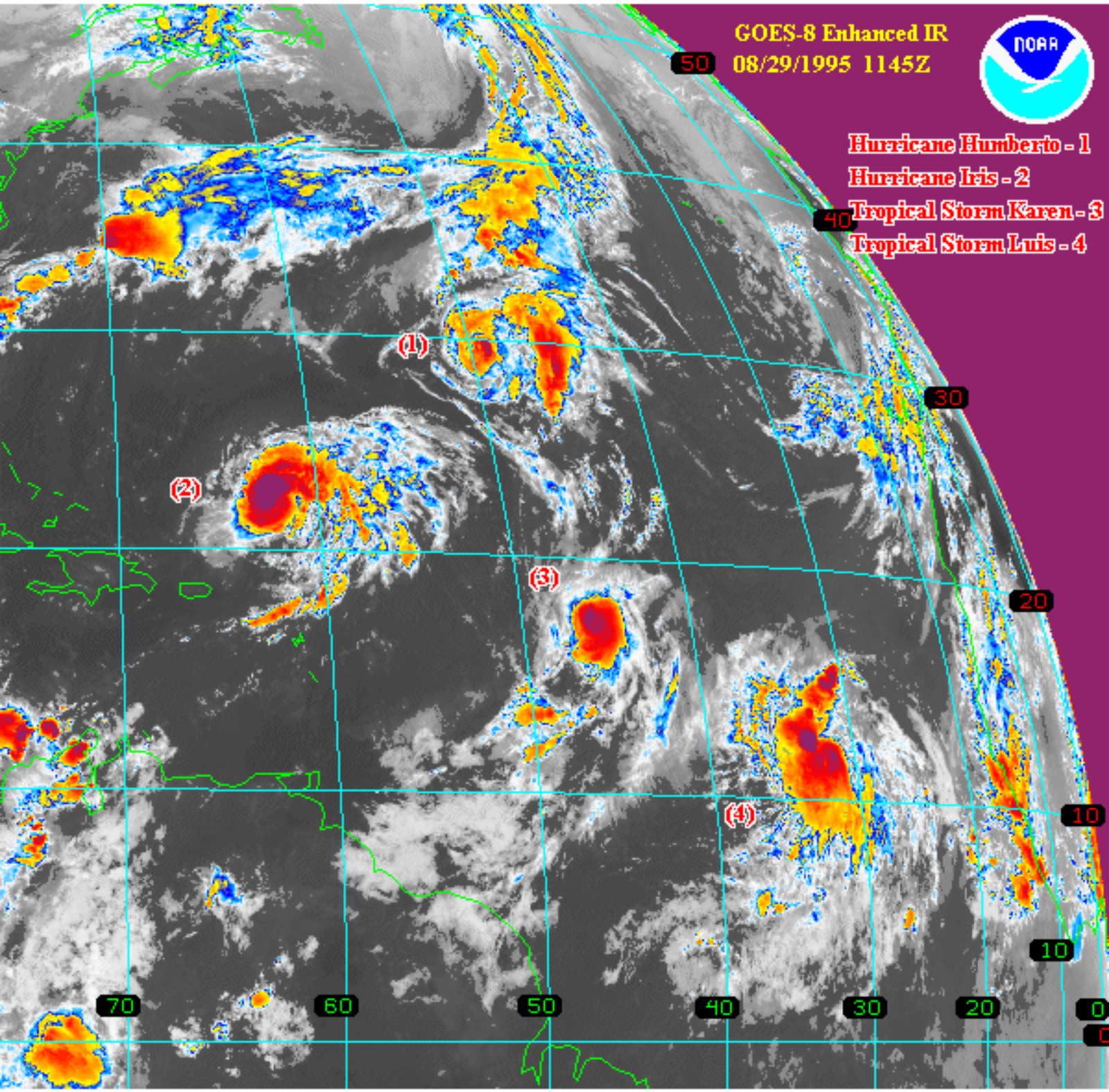
Technical Report 96-01 March 1996

1995 Atlantic Tropical Storms

Views from the NOAA Satellites



National Climatic Data Center
Research Customer Service Group

National Hurricane Center

Introduction

The report is a joint effort by two NOAA agencies, the National Climatic Data Center (NCDC) and the National Hurricane Center (NHC). The narrative portion of the report was derived from the Preliminary Hurricane Reports prepared by several research meteorologists at NHC, and the satellite imagery were provided by the NCDC. This report is considered to be preliminary with the intention to provide a brief synopsis of each named tropical system along with one or more satellite images of each storm taken by either the Geostationary Operational Environmental Satellite (GOES) or the Polar Orbital Environmental Satellite (POES). Full resolution satellite data and complete preliminary hurricane reports for each storm may be obtained from the National Climatic Data Center. The authors of and contributors to this report are:

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About NOAA's Satellites

The two primary satellite systems which produced the images for the report are the Geostationary Operational Environmental Satellite (GOES) and the Polar Orbiting Environmental Satellite (POES). Currently, there are two GOES satellites: GOES-8 at 75 West longitude and GOES-9 at 135 West longitude. GOES-9 replaced GOES-7 early in 1996 marking the end of the first generation of GOES satellites. The new series is now equipped with two separate, vastly improved, instruments, the imager and sounder, which now point to the earth continuously. The imager is equipped with 5 channels ranging from the visible (0.52um-0.72 um) to the longwave infrared (11.5um-12.5 um). The visible channel has a resolution of 1km and the majority of the infrared channels has a resolution of 4km. The sounder carries 18 thermal infrared channels, plus a low resolution visible channel. The new spectral channels, at wavelengths never attained before in geosynchronous orbit, are sensitive to temperature, moisture, and ozone. Each of the GOES satellites scans predetermined areas of the earth, which includes the continental United States at least four times an hour. In times of severe weather the GOES satellites are capable of one minute interval scanning.

The POES satellite system offers the advantage of daily global coverage, by making nearly polar orbits roughly 14.1 times a day. Since the number of orbits per day is not an integer the sub orbital tracks do not repeat on a daily basis, although the local solar time of the satellite's passage is essentially unchanged for any latitude. In operation are NOAA-12 and NOAA-14. The satellite system includes the AVHRR (Advanced Very High Resolution Radiometer) and the TOVS (Tiros Operational Vertical Sounder). The AVHRR is equipped with five spectral channels in wavelengths similar to the GOES imager. The TOVS carries three types of sensors, Microwave Sounding Unit (MSU), Stratospheric Sounding Unit (SSU), and High Resolution Infrared Radiation Sounder/2 (HIRS/2).

The infrared and visible satellite images in the report were created from either the GOES imager or the POES AVHRR instruments. The visible channel measures the reflectance of the objects scanned. Clouds are more reflective than surface objects which appear dark. The infrared channel measures emitted radiation from the earth and clouds at longer wavelengths than the visible channel, which gives it the advantage of "seeing" clouds at night. Another important advantage is that temperatures of cloud tops, land and oceans can be determined from the infrared channel. Colors can be assigned to predetermined temperature values to enhance key features on the satellite image. In this case, cloud tops are colored ranging from gray indicating the warmest cloud tops to maroon indicating the coldest cloud tops. Land and ocean features are warmer than the clouds and are assigned a black color. The table below shows the correlation between the color on the infrared images with the temperature. More information about NOAA's satellite systems can be obtained from the National Climatic Data Center.

Color vs. Temperature Conversion for Enhanced Infrared Images

Color	Temperature
Gray/Black	>=287.5 Kelvin (14.3C)
White	262.5K (-10.7C)
Light Blue	250.0K (-23.2C)
Blue	245.0K (-28.2C)
Yellow	238.0K (-35.2C)
Orange	223.0K (-50.2C)
Red	213.0K (-59.2C)
Maroon	<=203.0K (-70.2C)

Ordering and Accessing Data

The NCDC maintains and provides GOES and POES satellite data in various formats. Many of the images contained within this report are available in higher resolution on NCDC's Home Page on the Internet. The World Wide Web address is <http://www.ncdc.noaa.gov>. To order additional satellite data or preliminary hurricane reports, contact the NCDC at 704-271-4850 or e-mail your inquiry to satorder@ncdc.noaa.gov. The National Hurricane Center's Homepage on the WWW offers miscellaneous information on historical hurricanes, including seasonal tracks from 1961 to 1995, reconnaissance reports, current tropical cyclone activity, and much more. The WWW address is <http://www.nhc.noaa.gov/index.html>.

Summary of the Tropical Cyclone Activity for 1995

The 1995 Atlantic Hurricane Season will go down in the record books as the second busiest hurricane season since 1871. There were a total of 19 named storms, 11 of which reached hurricane strength. Only in 1933, with 21 known storms, did the number of tropical cyclones surpass 1995's count.

Five of the eleven hurricanes reached category 3 or higher on the Saffir/Simpson Hurricane Scale with sustained winds of 96kts or greater. Five tropical cyclones made landfall in the continental U.S., two of which were hurricanes Erin and Opal. Hurricanes Luis and Marilyn struck the northeastern Caribbean Islands and Hurricane Roxanne affected a large area of Mexico. Total damages are estimated to be over $8 billion for the U.S., the Caribbean, and Mexico. Estimates for the U.S., including the U.S. Virgin Islands, exceed $5 billion. These estimates are based on insured and uninsured property loses. Insured property loses are reported to the American Insurance Services Group. The National Hurricane Center estimates that uninsured losses usually match that of the insured losses. The overall death toll (direct causes) was 122, with 29 of those in the U.S.

Following is a synopsis of each storm.

Allison- Only three days into the official tropical storm season, Allison formed in the northwestern Caribbean and immediately headed northward toward the Florida panhandle. At the time the image was taken on June 4 (Fig 1), Allison was a marginal hurricane with top winds at 65kts. The visible image shown on Figure 2 was taken approximately an hour before Allison made landfall over Alligator Point, Florida. The center of circulation is shown with the heaviest of the squall bands (brighter clouds) spiraling well north and east of the center.

Barry- Tropical Storm Barry formed from a frontal low first detected between South Carolina and Bermuda. Figure 3 is a visible image of Barry with 60kt winds. Note that most of the convection with this storm is north of a relatively cloud-free center. The mid-Atlantic coast is shown at the upper left-hand corner.

Chantal- On July 5 a tropical wave moved off the west African coast By July 12 its circulation was organized enough to call it a tropical depression. Figure 4 shows Tropical Storm Chantal during the early morning hours of July 18 when it had 50kt winds. The low sun angle shows the circulation rather nicely. The storm at that time was heading north to northeastward missing Bermuda well to the west.

Dean- Dean briefly became a Tropical Storm on July 30 and moved inland just south of Galveston, Texas, later that day. Figure 5 shows a GOES-8 visible image of Dean along the Texas coast. There were no reports of injuries or deaths associated with Dean. However, heavy rainfall was a problem causing $500,000 in damages.

Erin- While Dean was dumping heavy rains along the Texas coast, Erin formed into a tropical storm from a vigorous wave over the southeastern Bahamas. An upper-level low near Florida slowed Erin's development somewhat, but by August 1 Erin became the second hurricane of the season. Figure 8 shows Hurricane Erin early in the day on August 1. Cyclonic circulation is evident in this image; however, there is no "eye," suggesting that the storm is a minimal hurricane. Hurricane Erin made landfall around 10 am EDT the next day near Vero Beach, Florida, as a category 1 hurricane on the Saffir/Simpson Hurricane Scale, with estimated winds of 75kts. As Erin crossed the central Florida peninsula it temporarily weakened to a tropical storm but soon regained its strength after emerging over the warm Gulf of Mexico waters late on August 2. Satellite images showed Erin forming an eye which indicates some strengthening. By early morning on August 3, Erin's sustained winds reached 85kts in a small area near its center when it came ashore near Fort Walton Beach, Florida. Figure 7 shows the

center of Erin moving through the Florida panhandle after making landfall. There were six fatalities and an estimated $700 million damage.

Felix- The first major hurricane of the season, Felix reached hurricane strength at 0000 UTC on August 11, while centered about 500 nautical miles east-northeast of the Leeward Islands. Felix continued to deepen and reached maximum strength at 1800 UTC on August 12 with sustained surface winds estimated at 120kts. Although Felix maintained hurricane strength for well over a week, it never regained its peak strength after the initial weakening. Despite that, Felix was a huge storm and affected much of the U.S. Atlantic seaboard as it meandered for many days. Figure 9 was taken by GOES-8, which shows a well formed minimal hurricane at about its closest approach to the U.S. coastline. Figure 10 is an infrared photo of Felix about a day later. Large swells created rip tide currents near the shorelines resulting in the drowning of eight swimmers, three off the North Carolina coast and five off the New Jersey coast. Felix affected Bermuda twice as it lingered.

Gabrielle- After moving across the Atlantic and Caribbean as a tropical wave, Gabrielle finally strengthened into a tropical storm early in the day on August 10. The storm gradually intensified to 60 knots by late on the 11th, just prior to making landfall just south of La Pesca, Mexico. Figure 6 shows Gabrielle with strong convection near the center.

Humberto- Hurricane Humberto remained in the eastern and central Atlantic from its inception and became extratropical several hundred miles to the west-northwest of the Azores. Its evolution included an interaction with Hurricane Iris when the latter was near the Lesser Antilles. Figure 11 shows Hurricanes Iris and Humberto from left to right with two well formed tropical waves moving off the western African coast. These two will later be named Karen and Luis.

Iris- Iris was the first of four consecutive tropical waves to form into a tropical storm. Iris' evolution and movement were greatly influenced by Humberto and Karen. Tropical Storm Iris moved through the islands of the northeastern Caribbean during late August and produced locally heavy rains and associated flooding. Three deaths occurred, two on the island of Martinique and one on the island of Guadeloupe. Figure 12 shows Hurricane Iris with 75kt winds. At this time Iris began a Fujiwhara effect with Tropical Storm Karen to the southeast. A Fujiwhara effect is where two storms begin moving about a central point between them, much like two ice skaters spinning around each other. The interaction swept the weaker Karen on a spiral path around and then into Iris where it was absorbed by September 3.

Jerry- Tropical Storm Jerry formed just offshore of southeast Florida early in the day on August 23. Jerry then made landfall near Jupiter, Florida, later that day and slowly moved northwestward then northward into Georgia over the next few days. Jerry will be remembered for producing heavy rainfall across the Carolinas with over 12 inches falling in the foothills of South Carolina. Six people died as a result of flash flooding. Figure 13 shows Jerry as a loosely organized tropical storm along the southeast Florida coast.

Karen- Not affecting land, Karen remained a minimal tropical storm. The center of circulation was absorbed by the stronger Hurricane Iris on September 3. Figure 14 shows Karen as a near minimal tropical storm. Hurricane Iris' circulation was affecting Karen at this time.

Luis- After Felix Hurricane Luis became the second category 4 storm. In its wake Luis left an estimated sixteen dead and two-and-a half billion dollars in damages on the northeastern most Leeward Islands. The Atlantic Ocean was already crowded with three other tropical systems, Humberto, Iris, and Karen when Luis became a tropical depression near Cape Verde on August 27. By the afternoon of August 30, Luis became the sixth hurricane of the season and continued to strengthen while moving west-northwestward. Figure 16 shows a large storm with a well defined eye. The most intense convection, shown in red, encircles the eye without any breaks, which is a sign of a very vigorous hurricane. The maximum sustained winds were estimated at 120kts at the time this image was taken. Figure 15 is a closeup visible image of Hurricane Luis taken early in the morning on September 6. The low sun angle provides a unique look of the swirling cloud tops and distinct eyewall. Days later, there was one storm related death in Newfoundland.

Marilyn- Marilyn became a tropical storm on September 13 and reached hurricane strength 24 hours later when a reconnaissance flight first identified a closed eyewall. Over the next three days the track turned more northwestward moving into the northeastern Caribbean Sea. Strengthening during this time was gradual. It hit the U.S. Virgin Islands late on September 15, which by then was a strong category 2 storm with 100kt winds. The strongest, most damaging part of the storm, the eastern and northeastern part of the eyewall, passed directly over St. Thomas Island. It caused 8 deaths and $1.5 billion in damages. Figure 18 shows an infrared satellite image of Hurricane Marilyn as its center approached St. Thomas Island. The storm appears well formed with a distinct, but relatively small eye. Figure 17 is a visible image taken by NOAA-14, showing Marilyn moving away from the Leeward Islands on September 16. The Dominican Republic is clearly shown to the west of the storm.

Noel- Noel was a marginal hurricane that remained at sea over the eastern Atlantic. Figure 19 shows Tropical Storm Noel just before it became a hurricane. The infrared image shows some organization with good convective activity. The center is ill defined.

Opal- The most destructive hurricane to hit the U.S. mainland since Hurricane Andrew, Opal will likely rank in the top ten list of costliest twentieth-century U.S. hurricanes after adjustments to inflation. Preliminary estimates of insured property damage for the U.S. is $2.1 billion with total damage estimates possibly reaching $3 billion. Opal became a tropical storm after emerging from the Yucatan Peninsula into the warm waters of the Bay of Campeche early in the day on September 30. Aircraft reports and satellite imagery suggested that Opal became a hurricane on October 2. A banding type eye appeared in satellite images later in the day while a large amplitude trough moving into the central United States began turning Opal toward the north. By early morning of October 3 the National Hurricane Center posted hurricane watches from Morgan City, Louisiana, to Suwannee River, Florida. Taking advantage of the 84F Gulf of Mexico water temperatures and upper-level anticyclone, Opal continued to strengthen. Opal was a category 4 hurricane on the Saffir/Simpson Hurricane Scale early on October 4 at which time reconnaissance aircraft reported a small 10 nautical mile diameter eye. The minimum central pressure was an amazing 916mb with estimated sustained surface wind velocities at 130kts. At this time Opal was 250 nautical miles south-southwest of Pensacola, Florida. Fortunately, Opal could not maintain peak intensity as the inner eyewall collapsed within a few hours. Figure 21 is a visible GOES image taken 6 hours before Opal made landfall. Note that the eye is no longer apparent. The first outer convective band has moved over the Gulf Coast. The solid mass of clouds across Mississippi, Alabama and Northern Georgia is associated with a frontal system. Figure 22 shows Opal making

landfall at Pensacola Beach, Florida. The maximum sustained winds were 100kts near the center of the storm. Although winds were diminishing at the time of landfall, extensive damage due to storm surge and breaking waves occurred over most of the coastal areas of the Florida panhandle. The estimated U.S. death toll from direct causes is 9.

Pablo- Pablo was a Cape Verde-type tropical storm that did not effect land. Figure 20 shows Tropical Storm Pablo with estimated winds of 50kts.

Roxanne- Roxanne was the first October hurricane that formed and reached category 3 on the Saffir/Simpson Hurricane Scale in the western Caribbean Sea since Hurricane Hattie (category 4) in October 1961. Roxanne formed from a complex combination of several large scale features: an upper level trough, broad surface low pressure area and a tropical wave. Early on October 10, Roxanne became the tenth hurricane of the season. Roxanne strengthened to a category 3 hurricane just as its center passed near the southern tip of Cozumel Island. Figures 23 and 24 are GOES-8 visible and infrared images, respectively, showing Roxanne approaching the Yucatan Peninsula. The eye is well-formed indicative of a vigorous hurricane. The estimated sustained winds were between 95 and 100kts. The hurricane crossed the Yucatan Peninsula and entered the Bay of Campeche and weakened to a tropical storm as it lingered near the west coast of the peninsula. It wandered over the southwestern Gulf of Mexico for nine days. In that time Roxanne restrengthened into a hurricane and then finally weakened to dissipation just offshore the coast of Mexico near Veracruz. Because Opal affected similar areas just 2 weeks earlier, it is difficult to separate damages from both storms. According to insurance company estimates, best estimate of the combined damage is $1.5 billion. Roxanne was responsible for 14 deaths.

Sebastien-Tropical Storm Sebastien originated from a tropical wave that moved westward across the Atlantic Ocean from October 13 through the 19. Sebastien became a tropical storm on October 21 and reached peak intensity on the 22 based on a ship observation. The presence of a southwesterly vertical wind shear precluded significant development. The colder cloud tops were displaced about 100 miles to the east and northeast of the center exposing the low level circulation as shown on Figure 25. It dissipated as it moved near the Virgin Islands.

Tanya- Hurricane Tanya formed in the central Atlantic Ocean from a tropical wave originating from the west African coast. This wave followed the one that spawned Tropical Storm Sebastien. By October 27 surface observations indicated a definite closed surface circulation and became a marginal hurricane early October 29. Influenced by a strong eastward moving trough and associated cold front near Bermuda, Tanya began to turn northeastward. Figure 26 shows Tanya, as a small hurricane embedded in a narrow wedge of warmer air between cooler air masses over the western and eastern Atlantic. Tanya reached peak intensity of 75kts on October 31. Tanya brought gale force winds over the Azores before merging with a large low pressure system over the north Atlantic by November 3.

1995 ATLANTIC BASIN TROPICAL STORMS AND HURRICANES

	Name	Dates	Minimum Pressure (millibar)	Max Wind Speed*	Cat **	Deaths ***	U.S. Damages
1	Allison	6/03- 6/06	987	65 kts	1	1	$1.7 million
2	Barry	7/06- 7/10	989	60 "	N/A	0	none reported
3	Chantal	7/12- 7/20	991	60 "	N/A	0	" "
4	Dean	7/28- 8/02	999	40 "	N/A	0	$.5 million
5	Erin	7/31- 8/06	973	85 "	2	6	$700 million
6	Felix	8/08- 8/22	929	120 "	4	8	none reported
7	Gabrielle	8/09- 8/22	988	60 "	N/A	0	" "
8	Humberto	8/22- 9/01	968	95 "	2	0	" "
9	Iris	8/22- 9/04	965	95 "	2	3	" "
10	Jerry	8/22- 8/28	1002	35 "	N/A	6	$27 million
11	Karen	8/26- 9/03	1000	45 "	N/A	0	none reported
12	Luis	8/27- 9/11	935	120 "	4	17	#
13	Marilyn	9/12- 9/22	949	100 "	3	8	$1.5 billion
14	Noel	9/26-10/07	987	65 "	1	0	none reported
15	Opal	9/27-10/05	916	130 "	4	59	$3.0 billion
16	Pablo	10/04-10/08	994	50 "	N/A	0	none reported
17	Roxanne	10/07-10/21	956	100 "	3	14	##
18	Sebastien	10/20-10/25	1001	55 "	N/A	0	none reported
19	Tanya	10/27-11/01	972	75 "	1	0	" "

* Estimated maximum 1-minute average wind speed

** Saffir-Simpson Hurricane Scale: cat 1=64-82 kts, cat 2=83-95 kts, cat 3=96-113 kts, cat 4=114-135 kts, cat 5=over 135 kts

***Estimated deaths from direct causes for the U.S., Caribbean, and Mexico.

$2.5 B non-U.S. damage; ## $1.5B combined damage in Mexico from Opal and Roxanne

Table of Figures

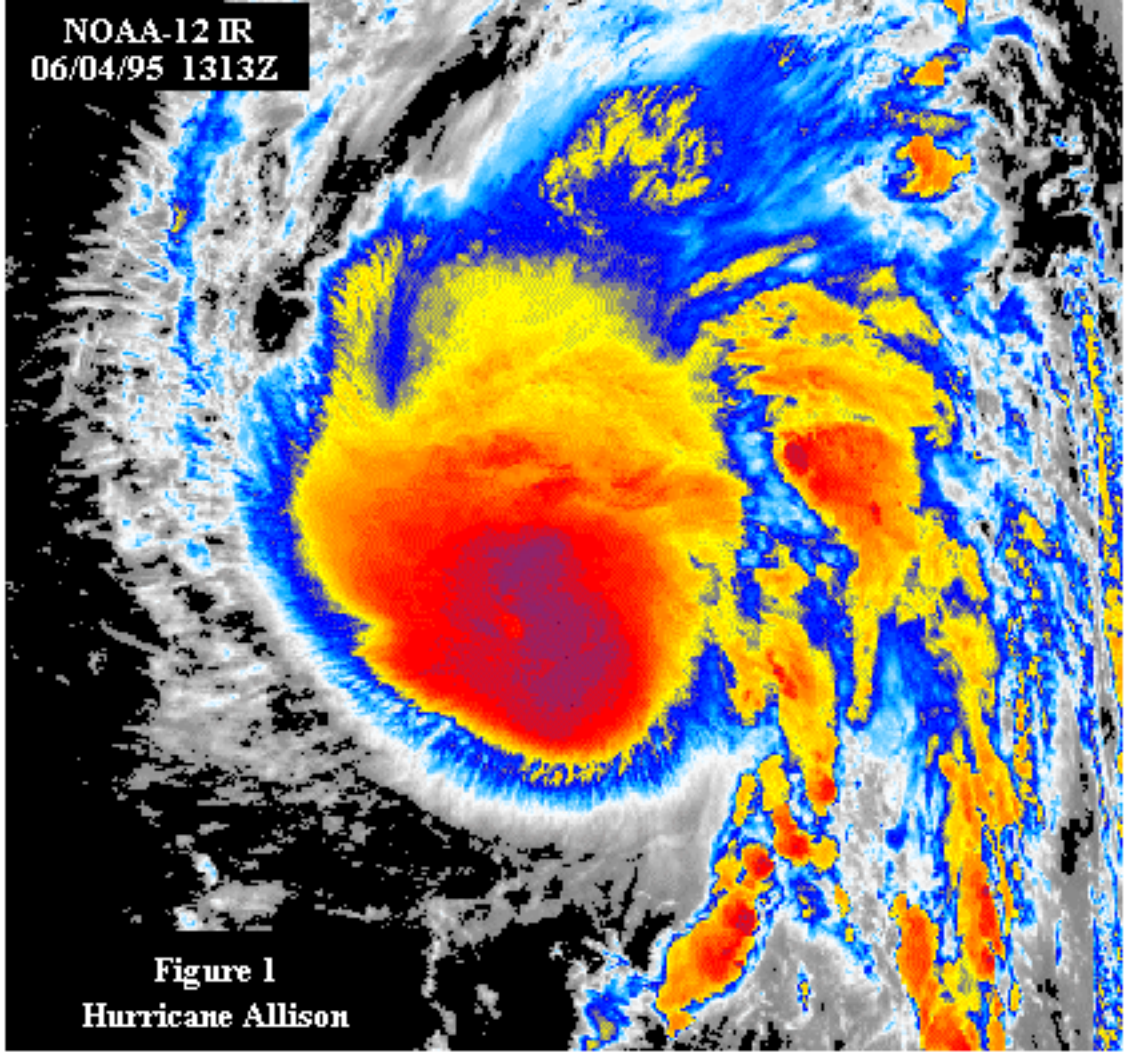


Figure 1
Hurricane Allison

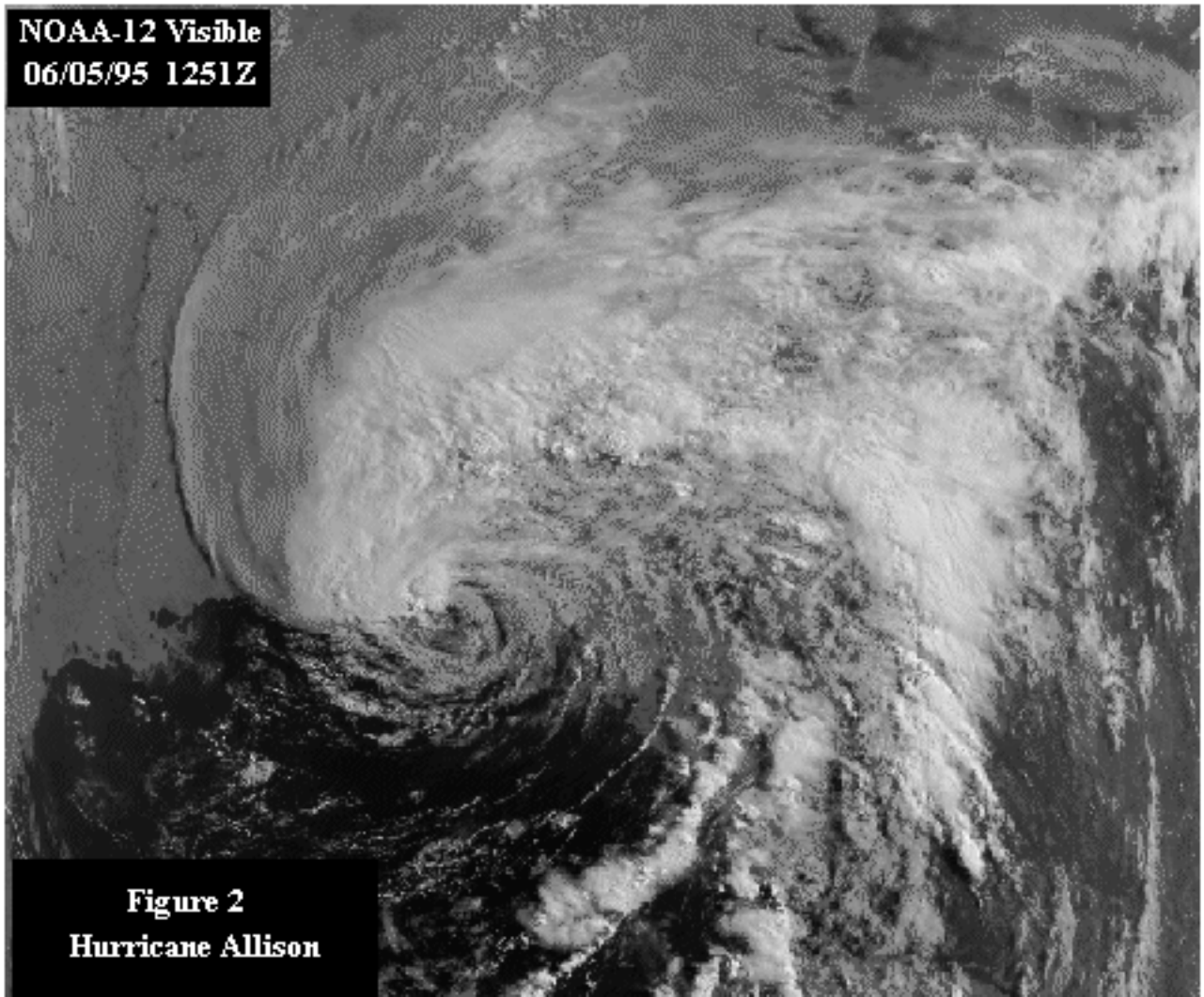


Figure 2
Hurricane Allison

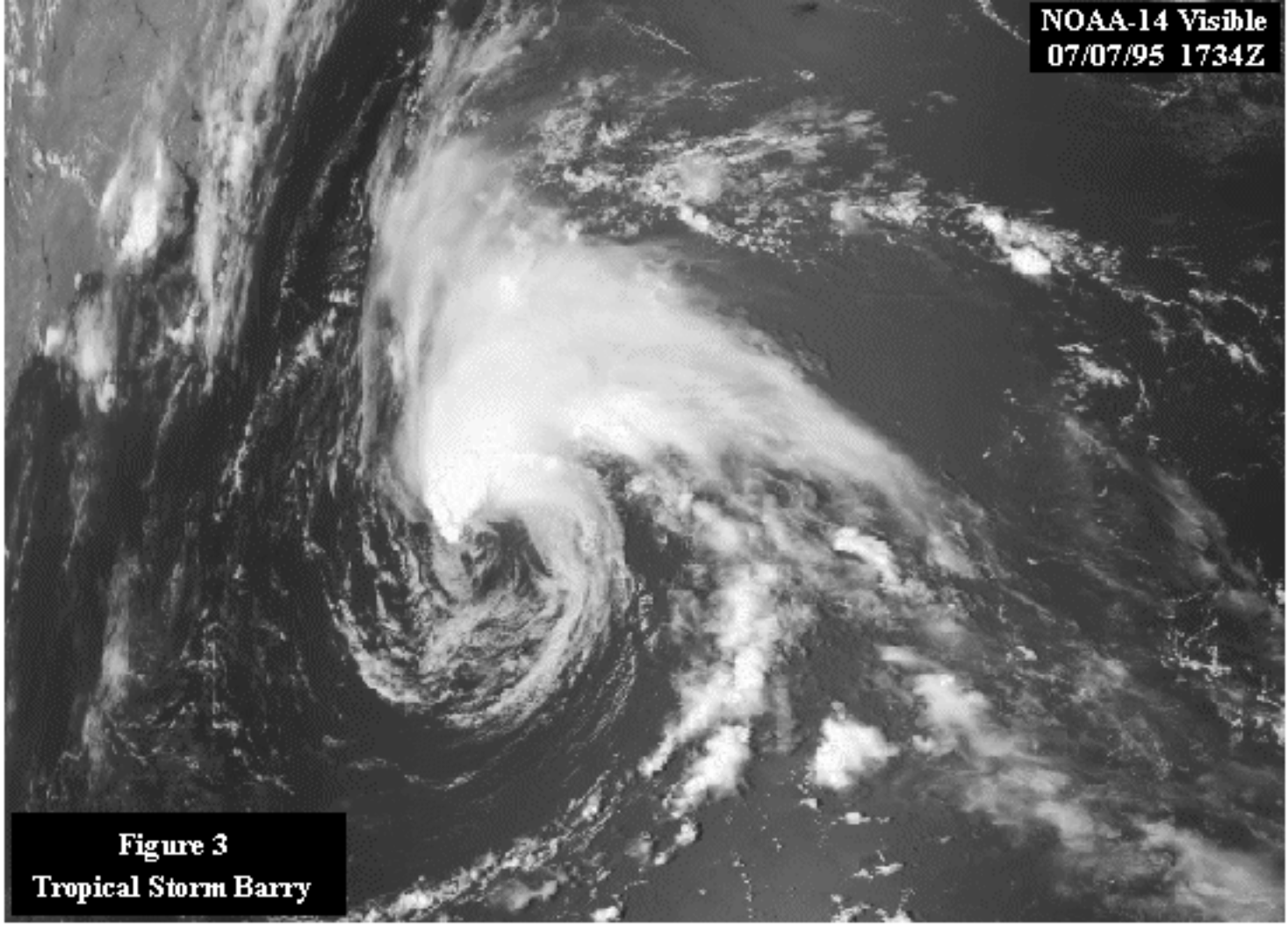


Figure 3
Tropical Storm Barry

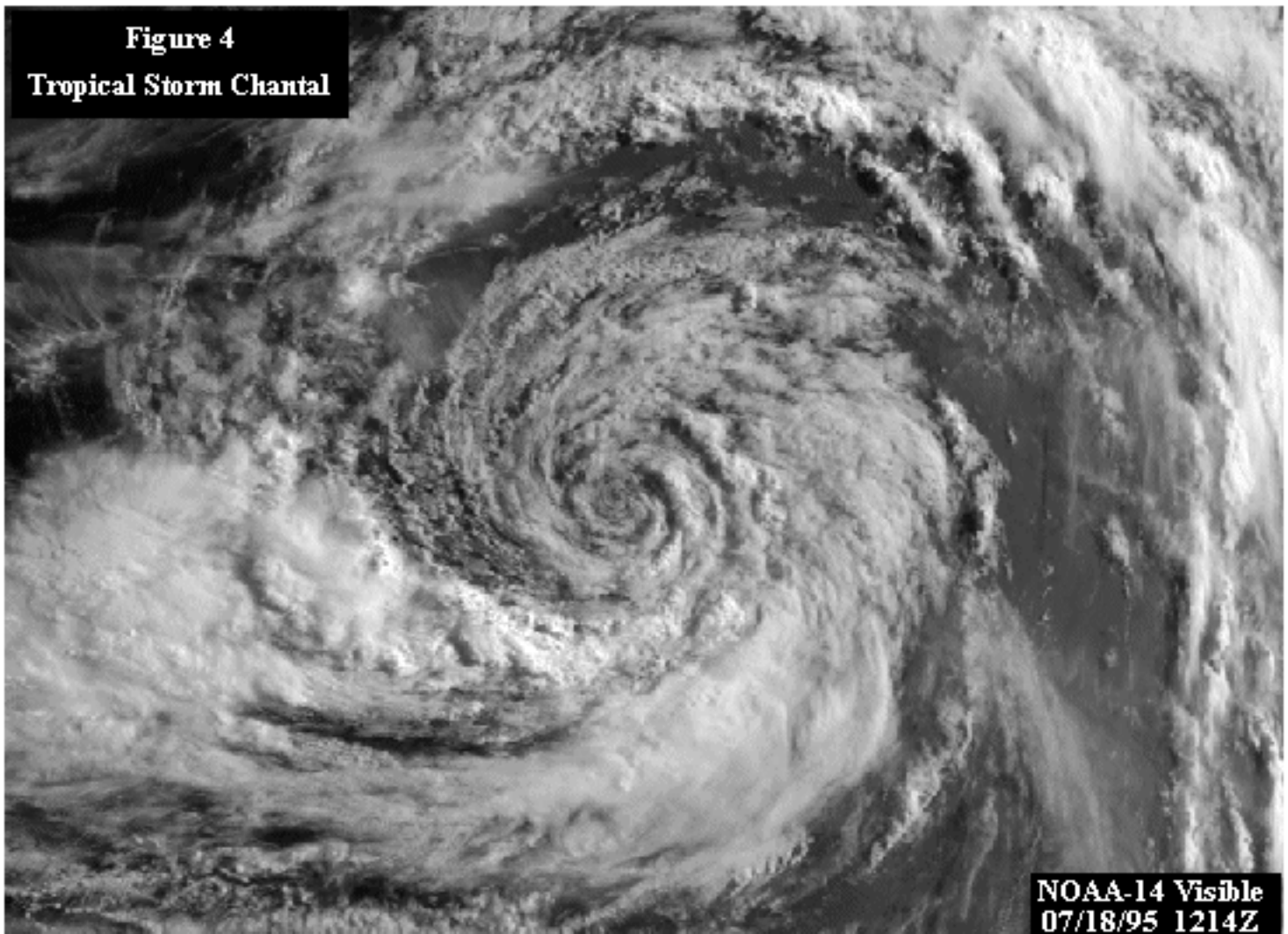


Figure 4
Tropical Storm Chantal

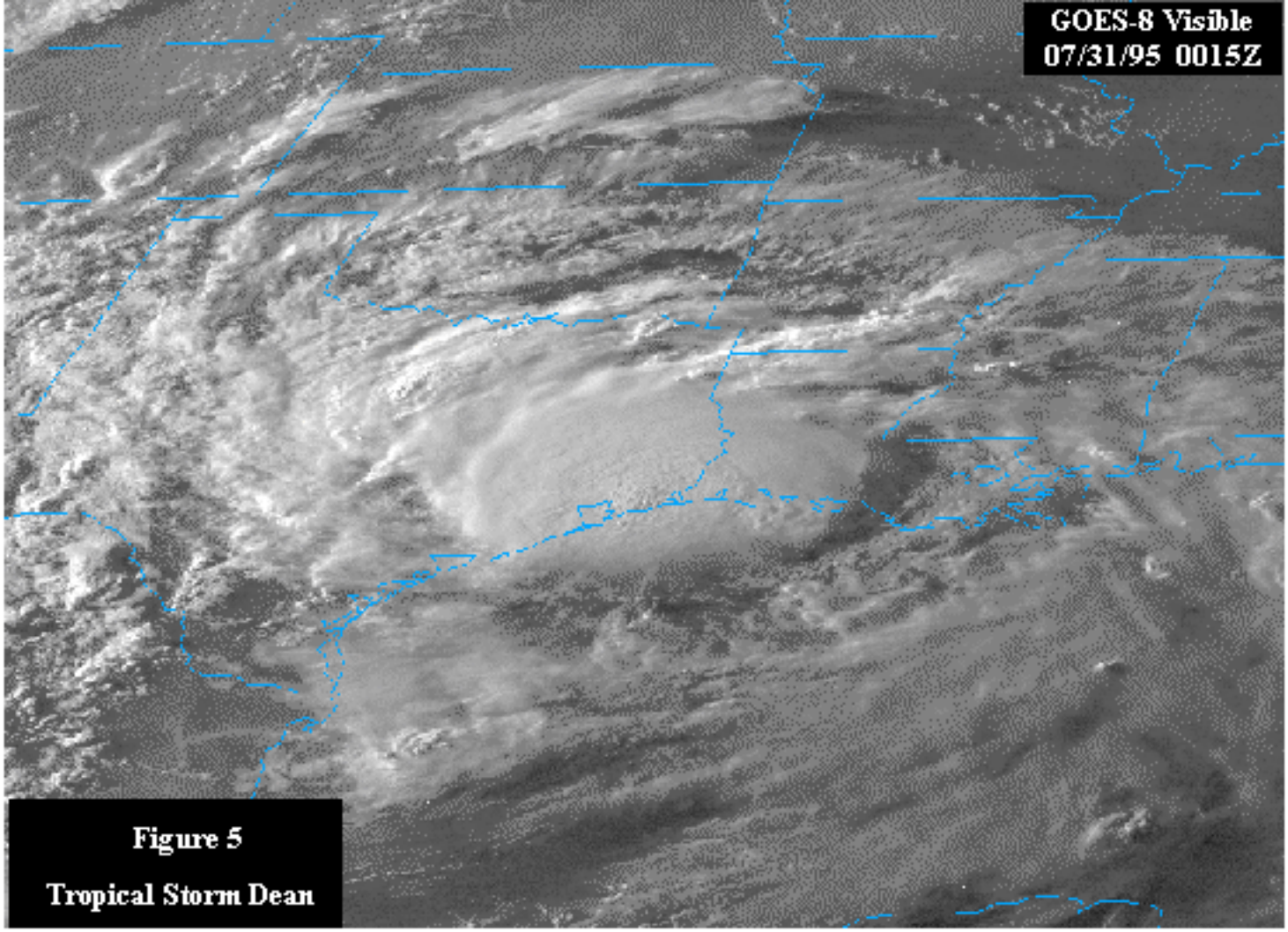
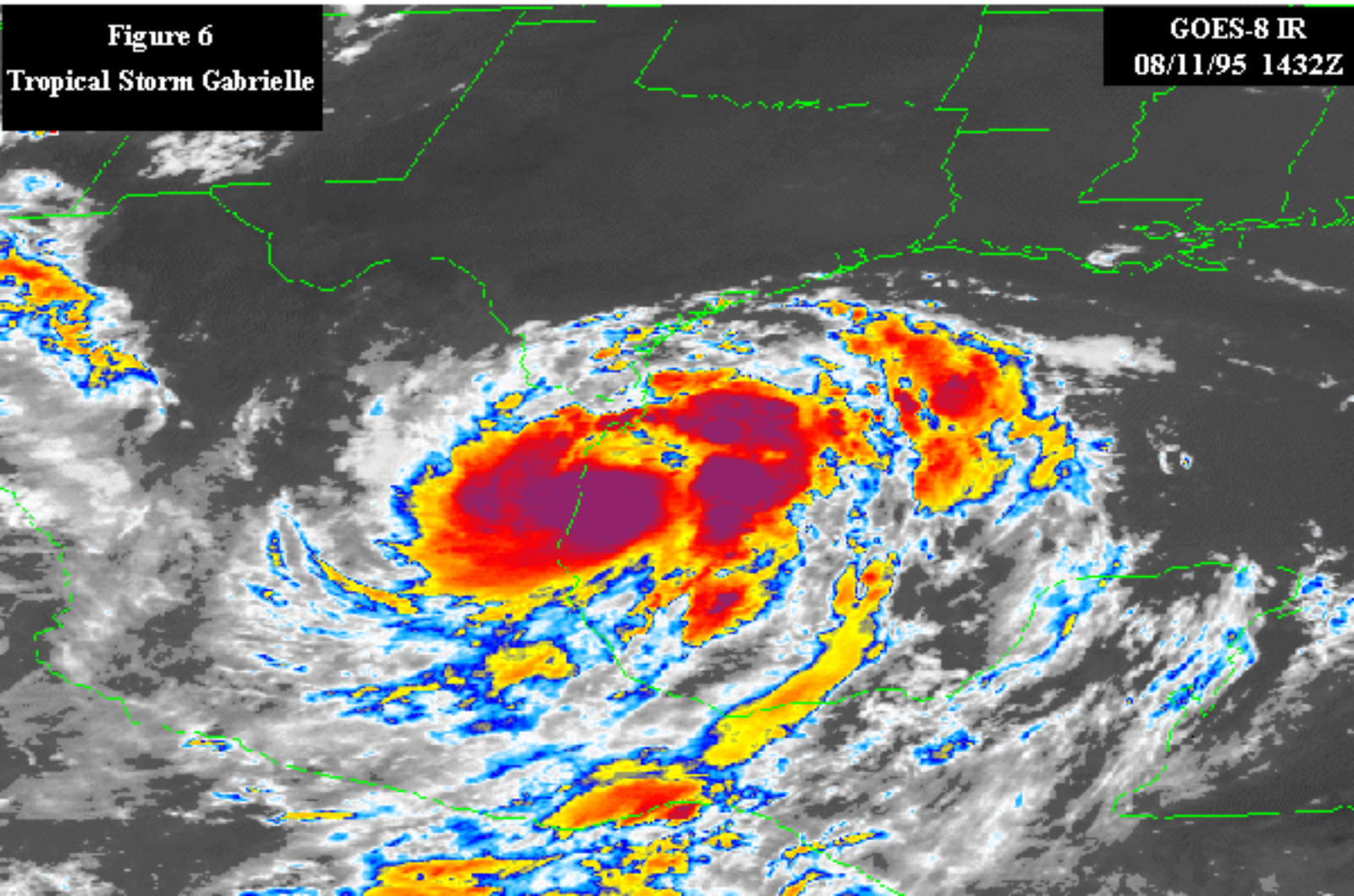


Figure 5

Tropical Storm Dean

Figure 6

Tropical Storm Gabrielle



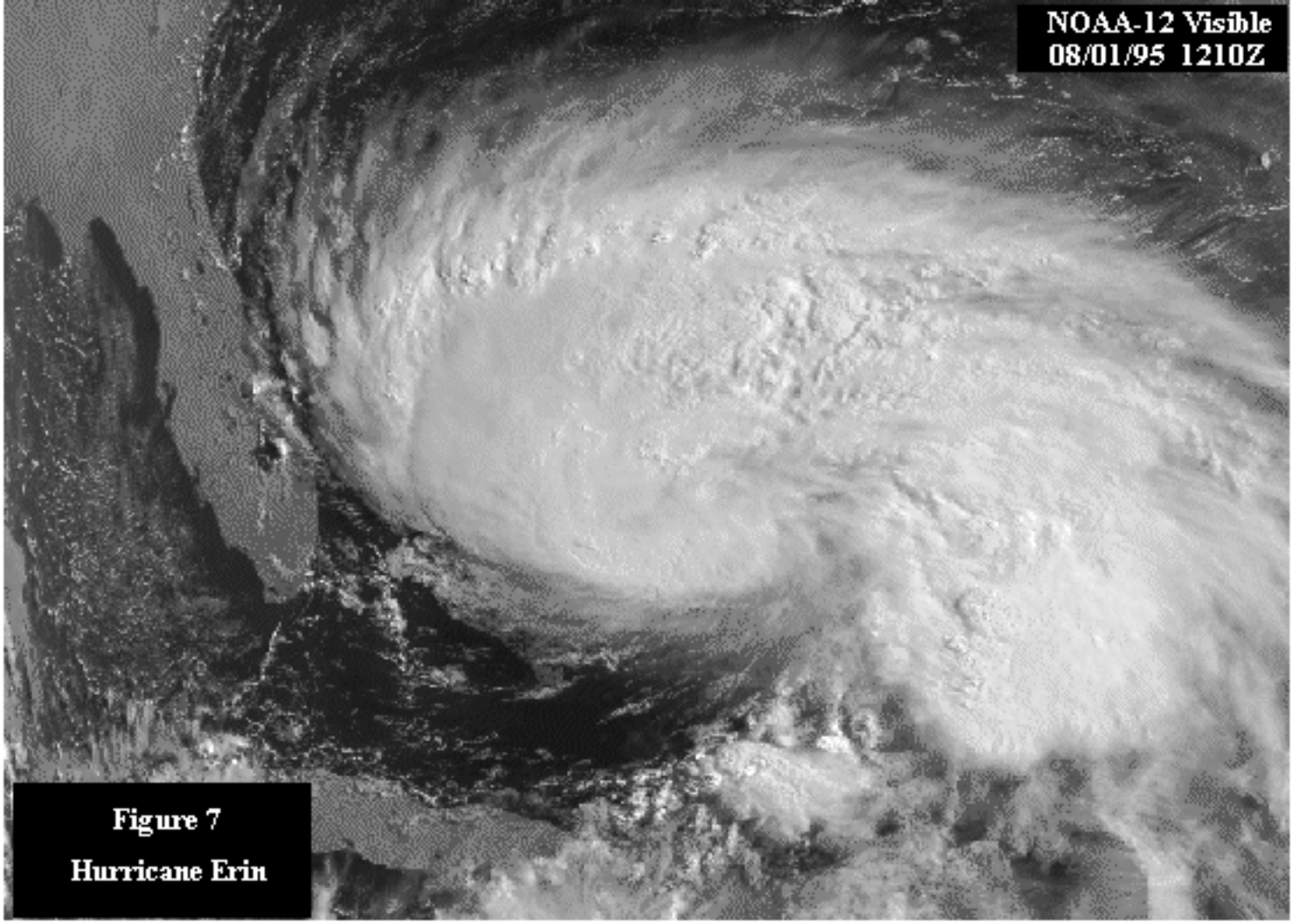


Figure 7
Hurricane Erin

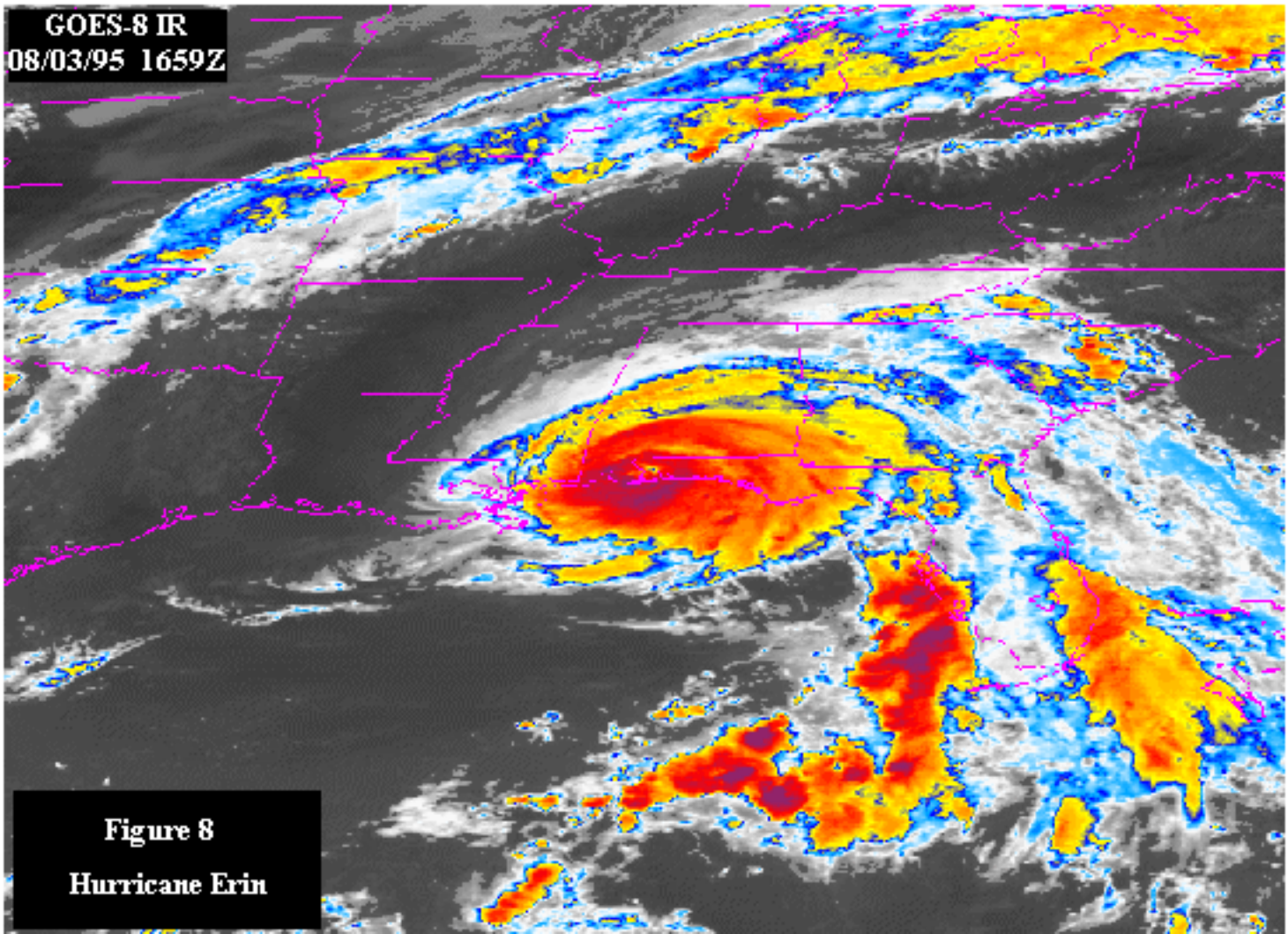


Figure 8
Hurricane Erin

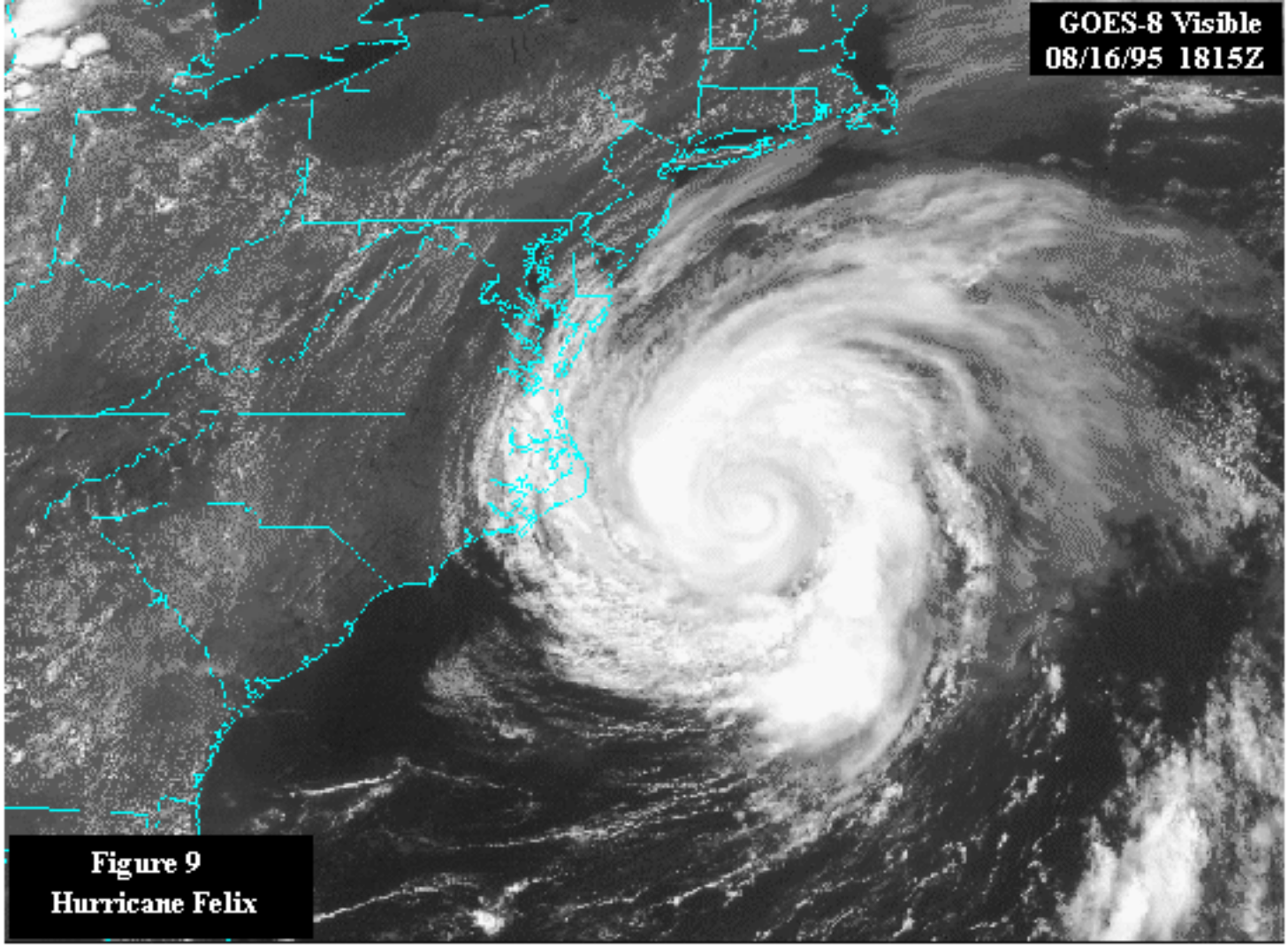


Figure 9
Hurricane Felix

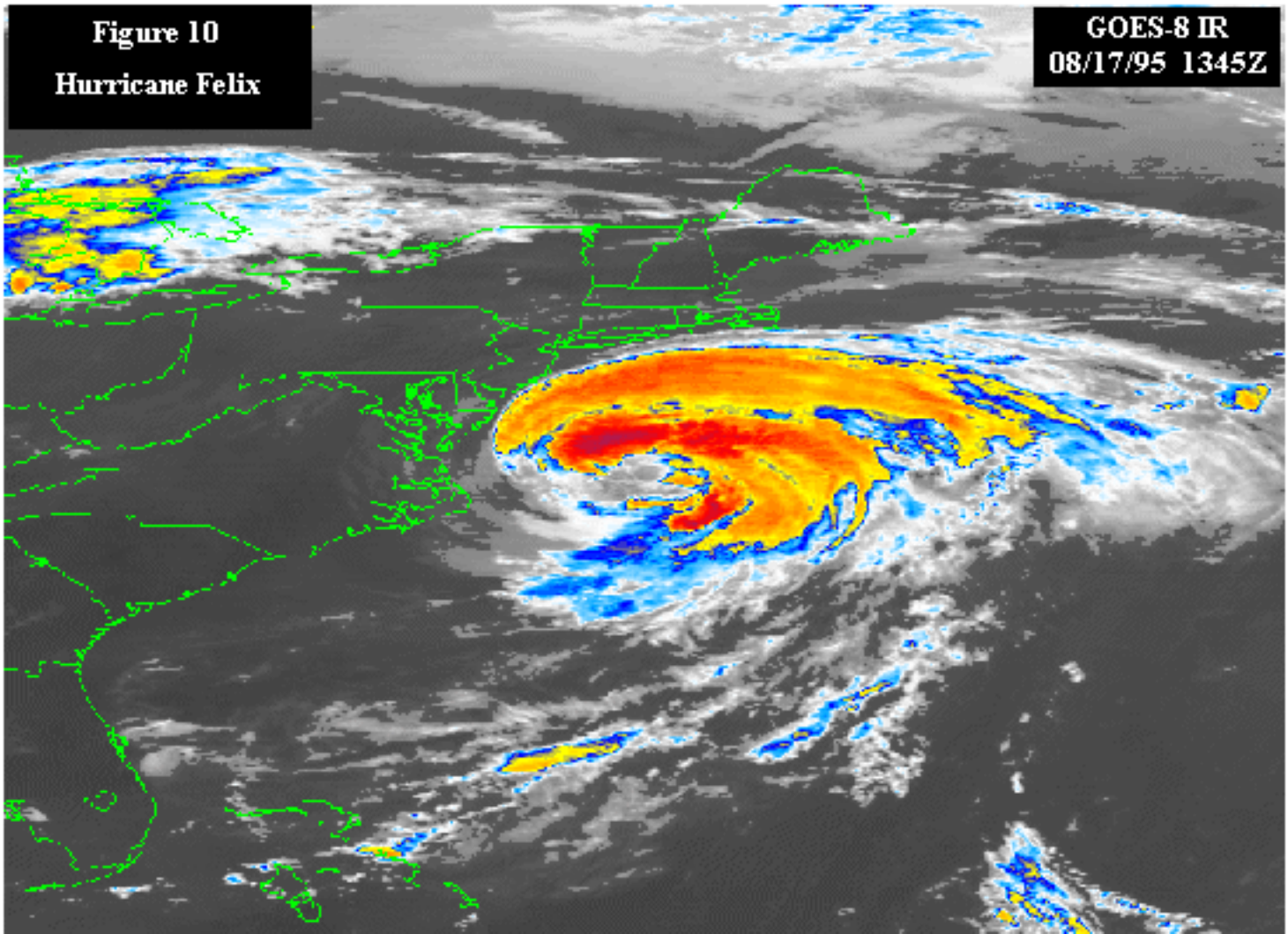


Figure 10
Hurricane Felix

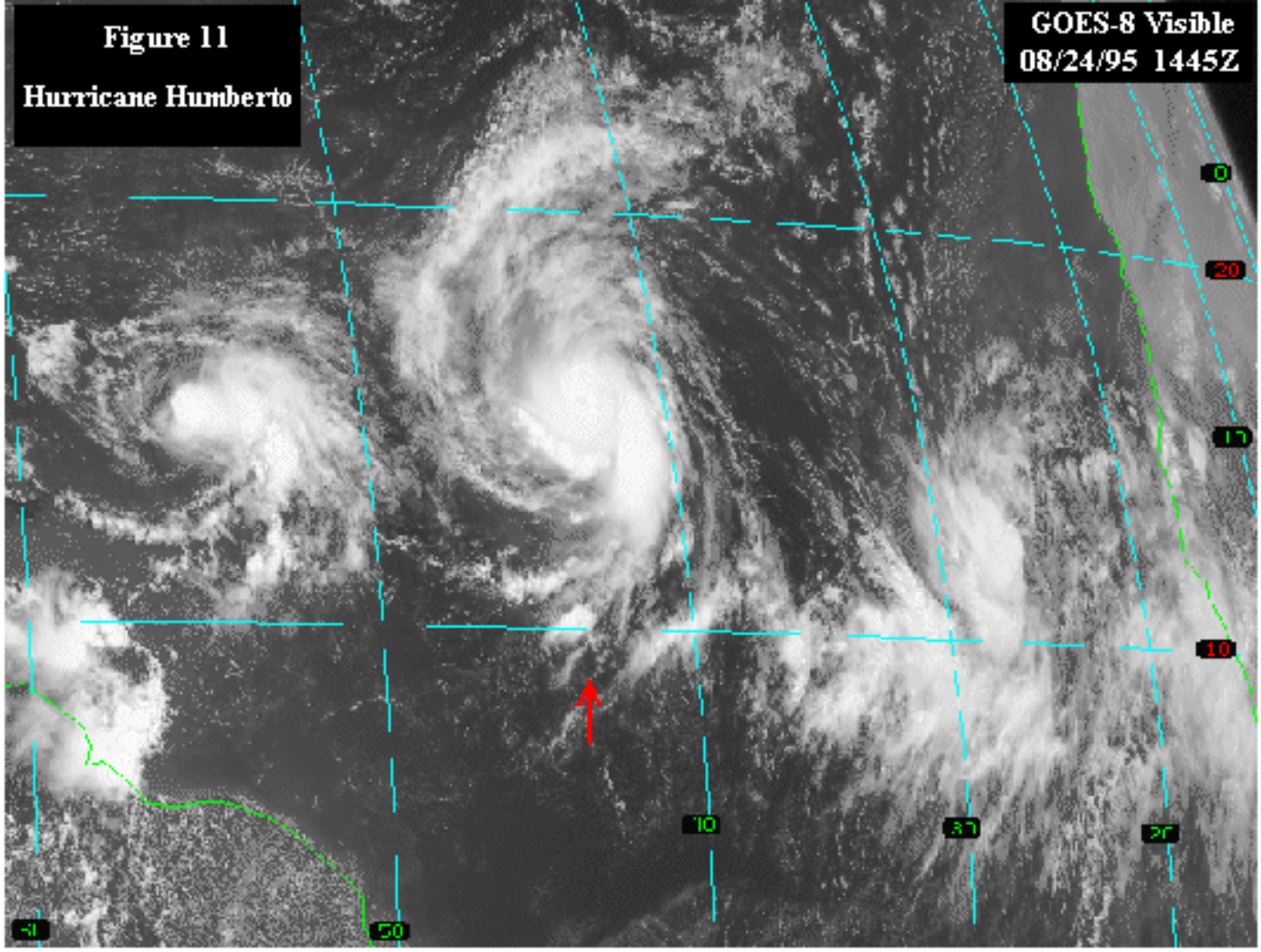


Figure 11
Hurricane Humberto
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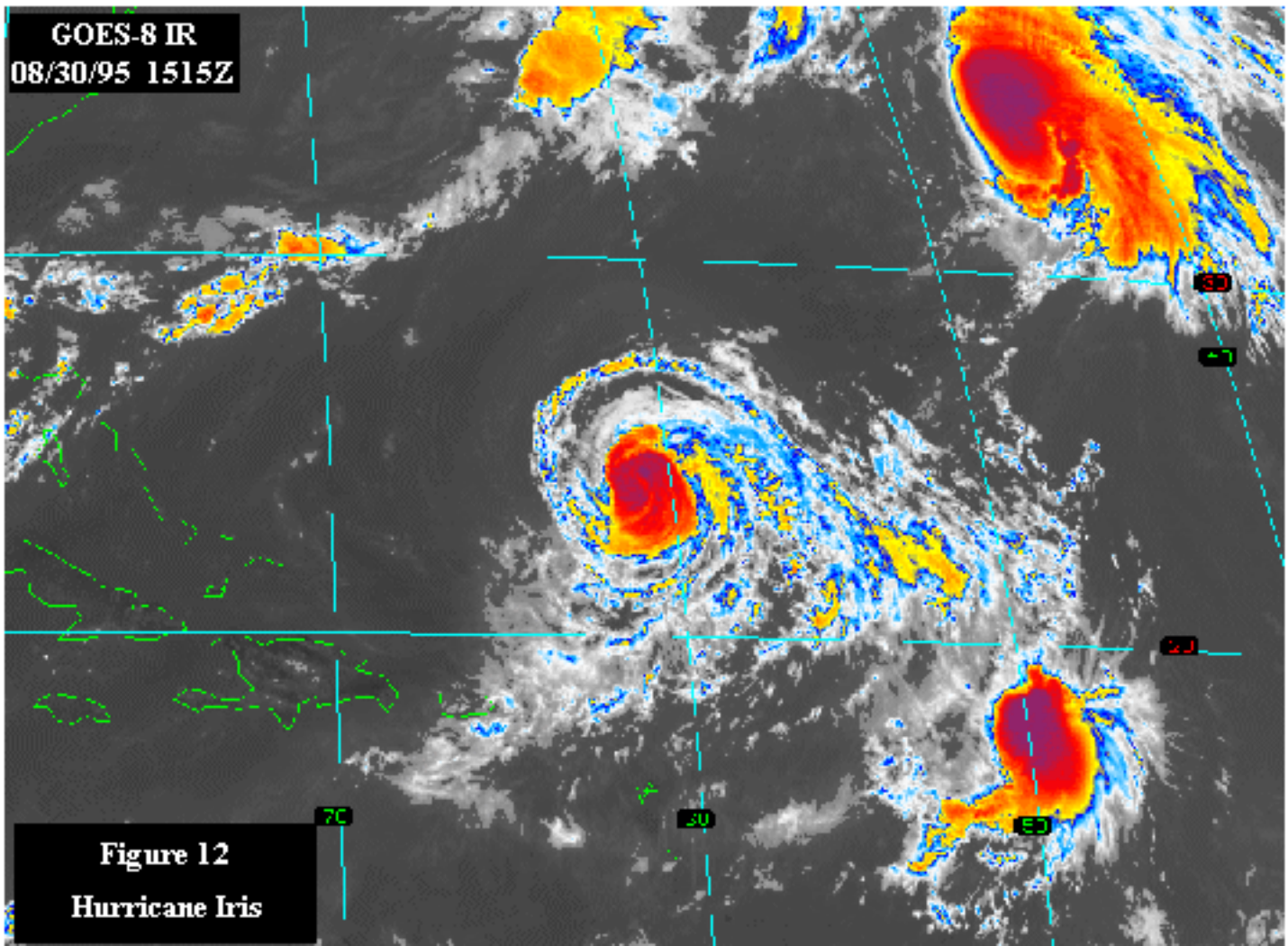

GOES-8 IR
08/30/95 1515Z
Figure 12
Hurricane Iris

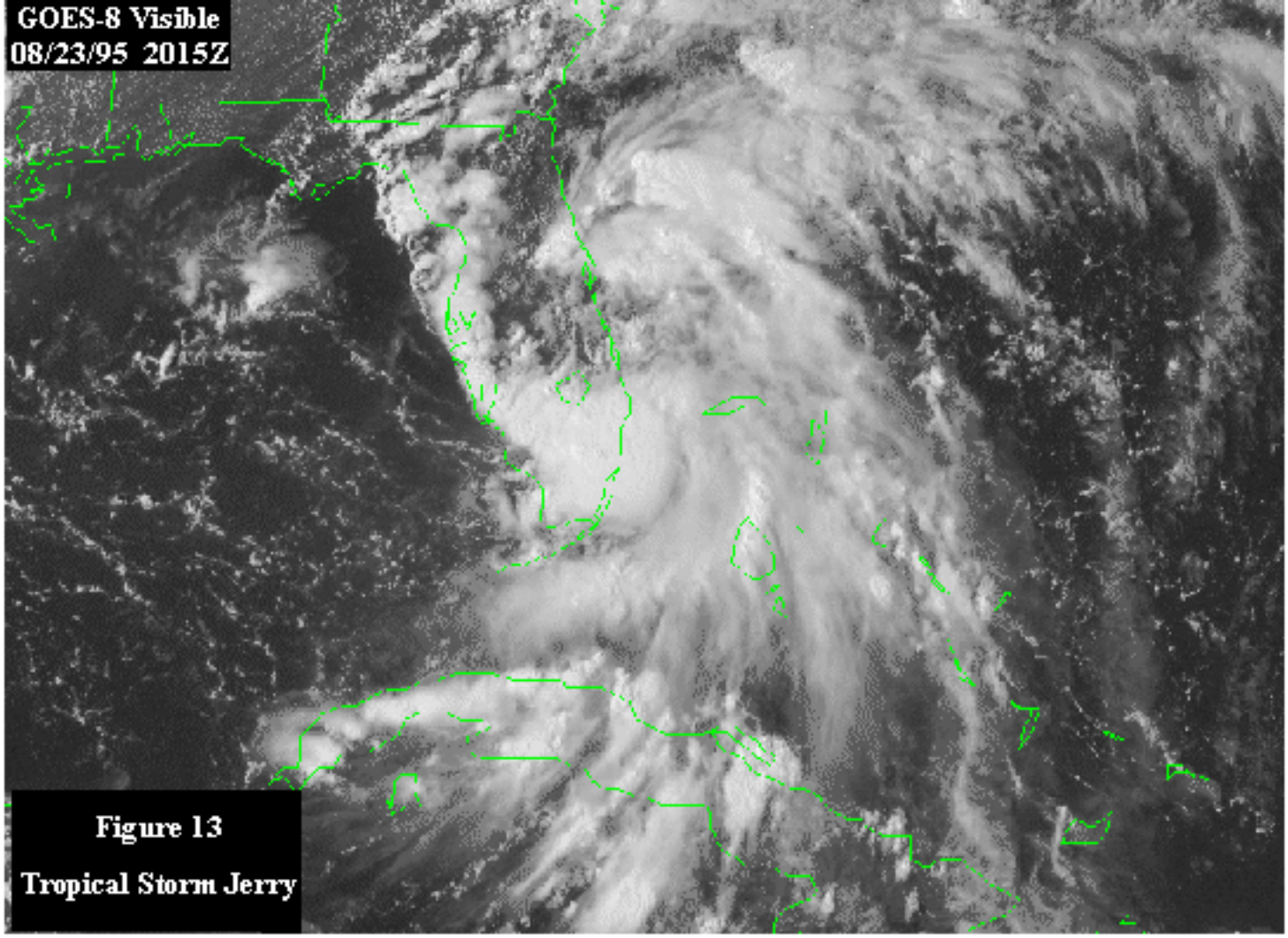


Figure 13

Tropical Storm Jerry

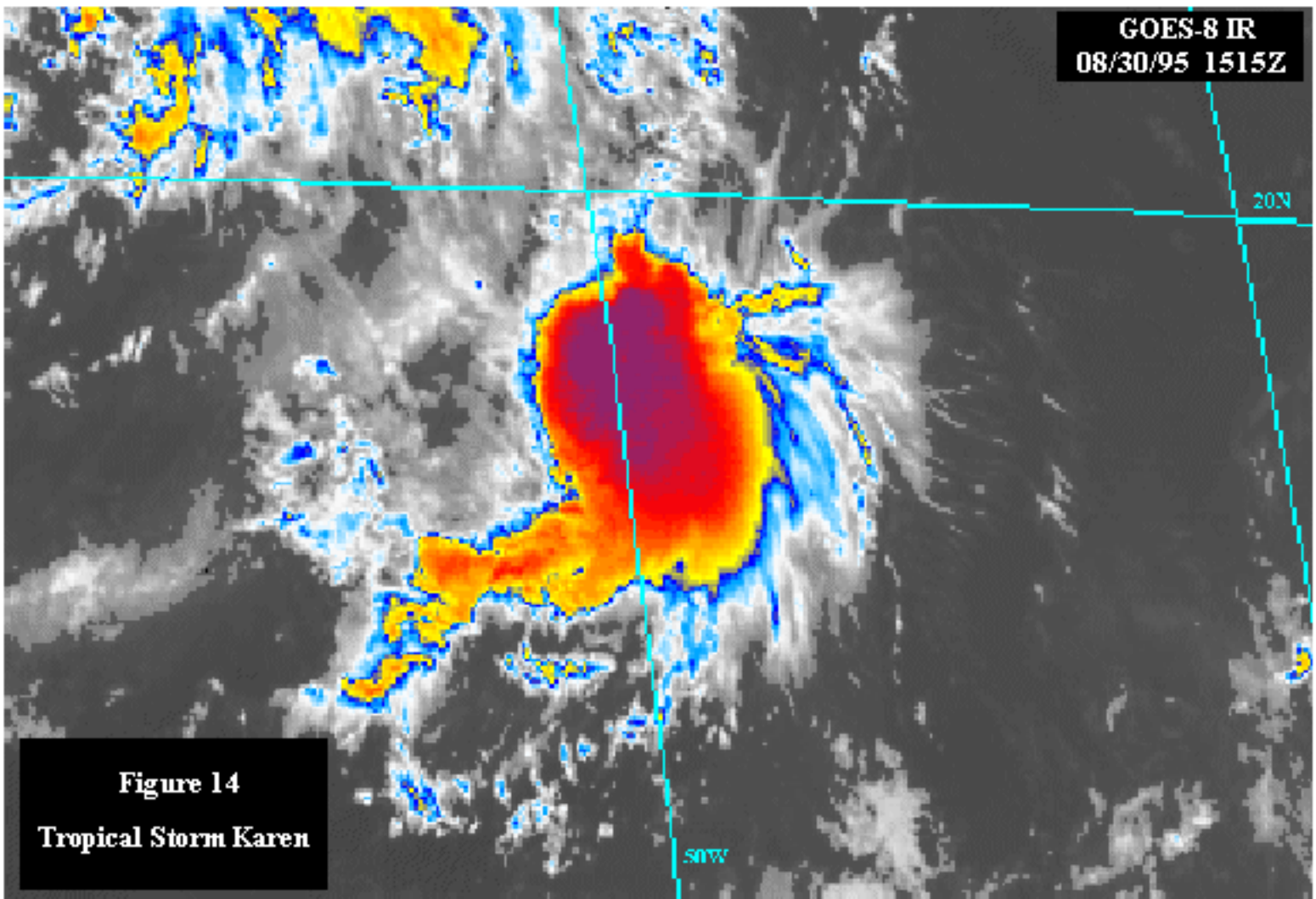
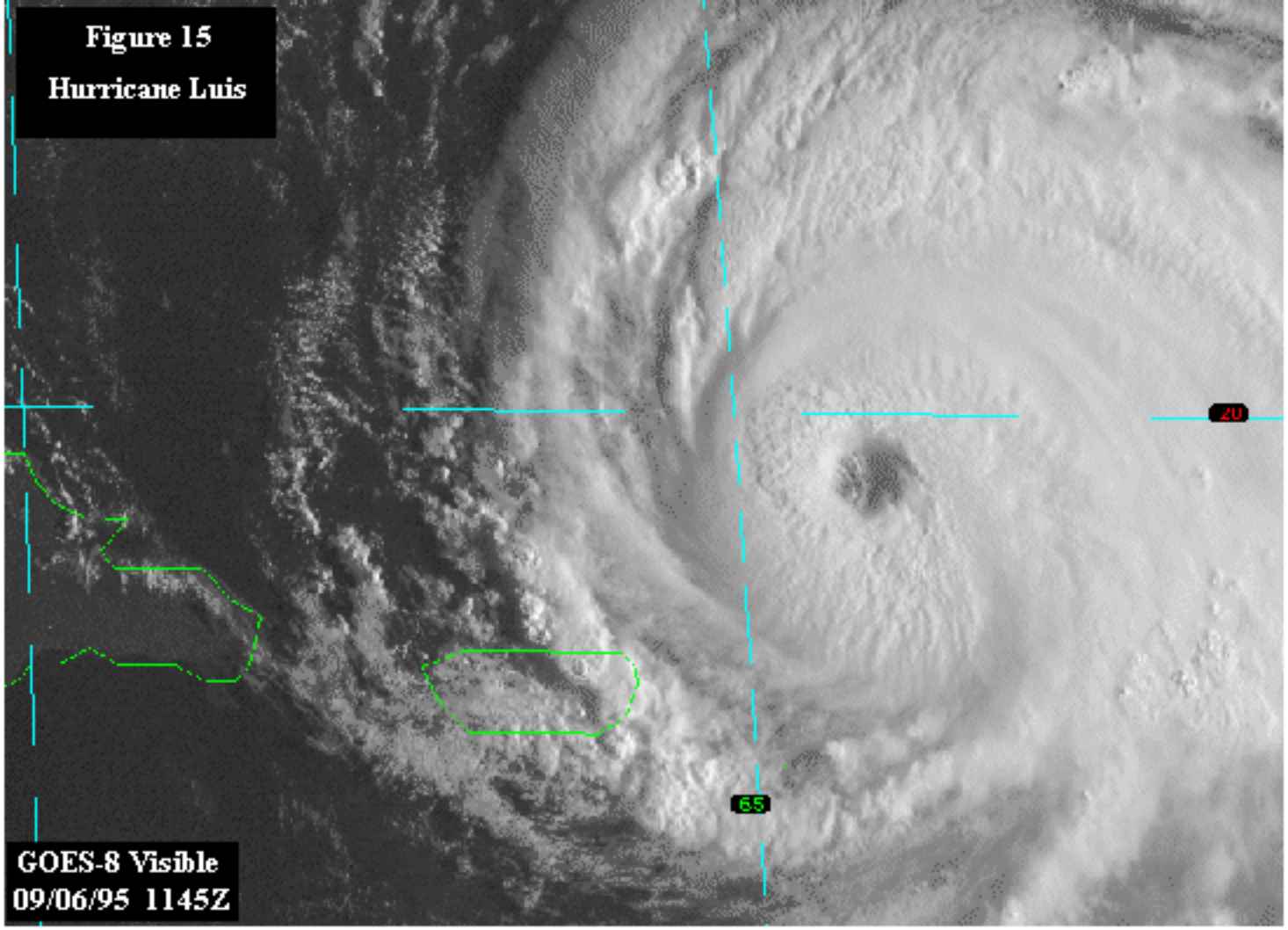


Figure 14

Tropical Storm Karen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Hurricane Luis
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65
GOES-8 Visible
09/06/95 1145Z

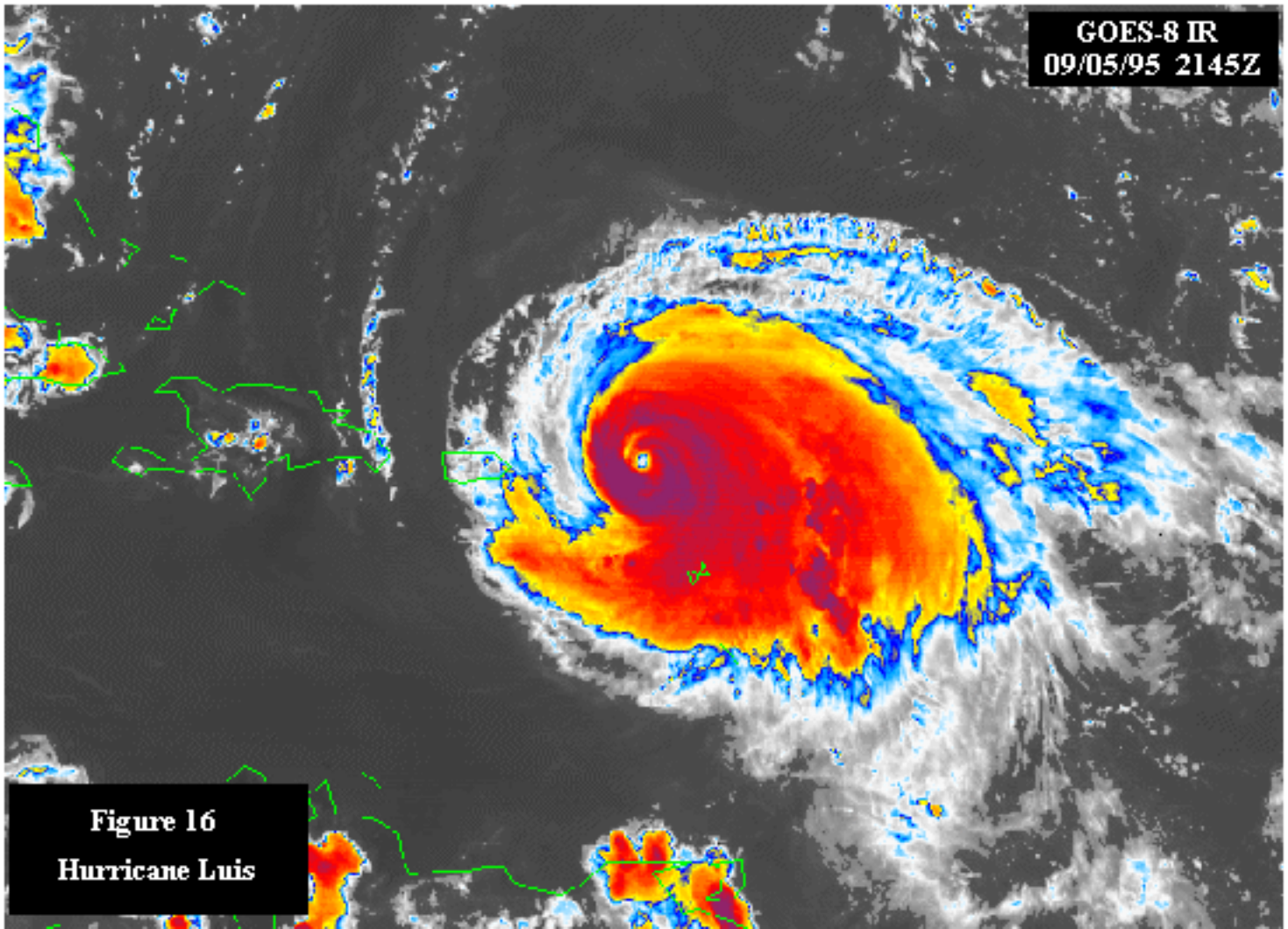
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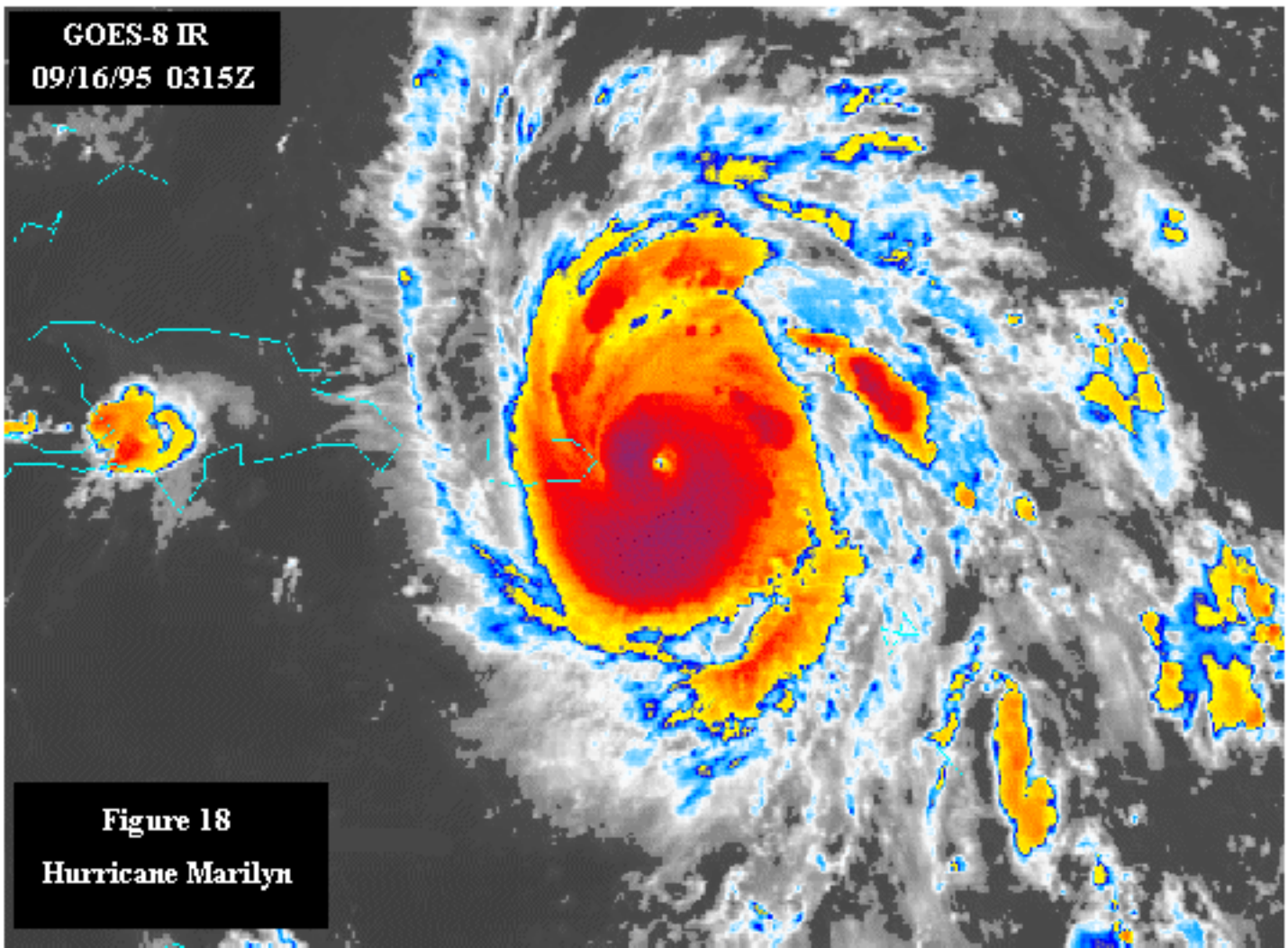
Figure 16
Hurricane Luis

Figure 17
Hurricane Marilyn



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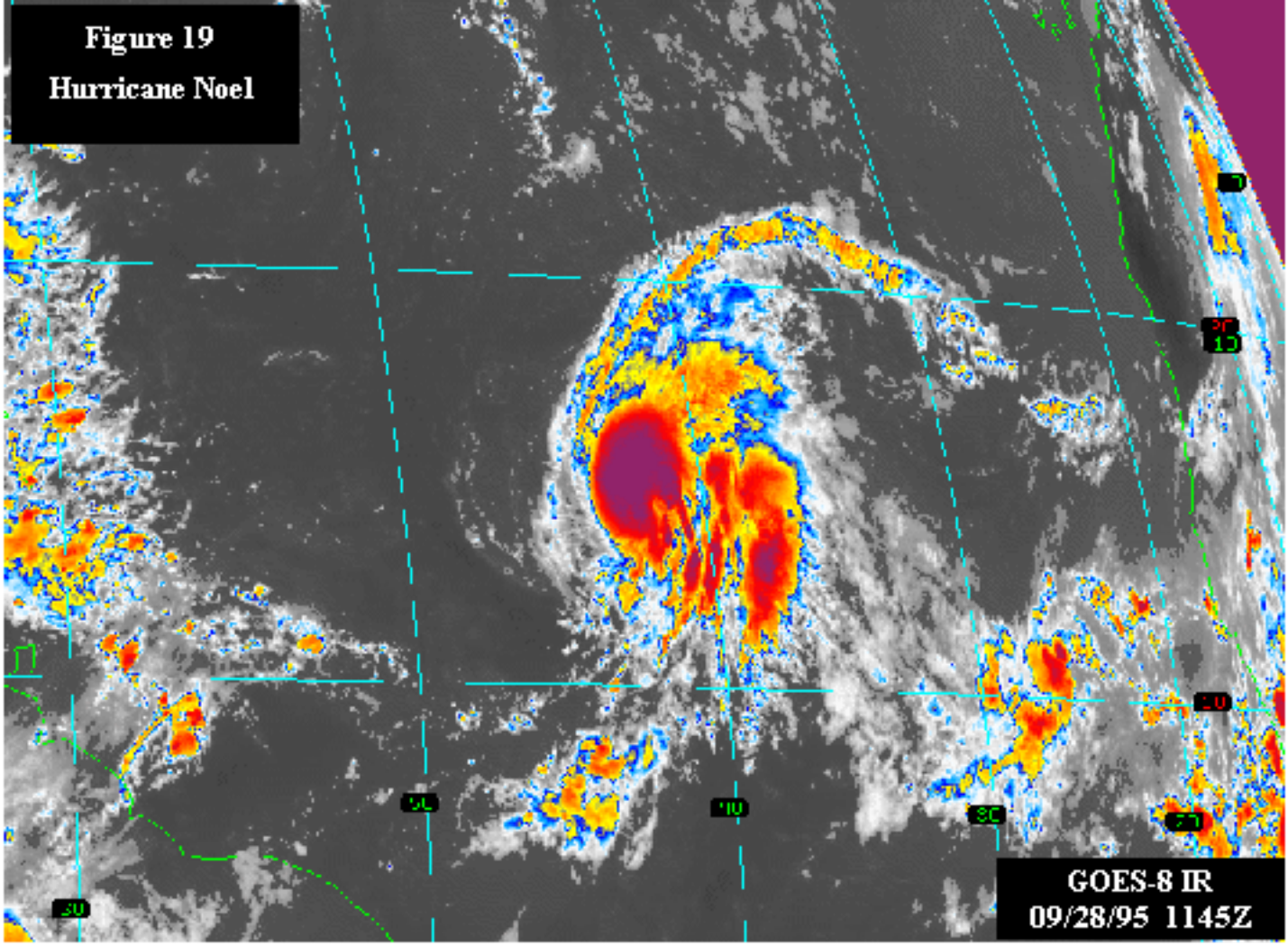
Hurricane Marilyn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Hurricane Noel
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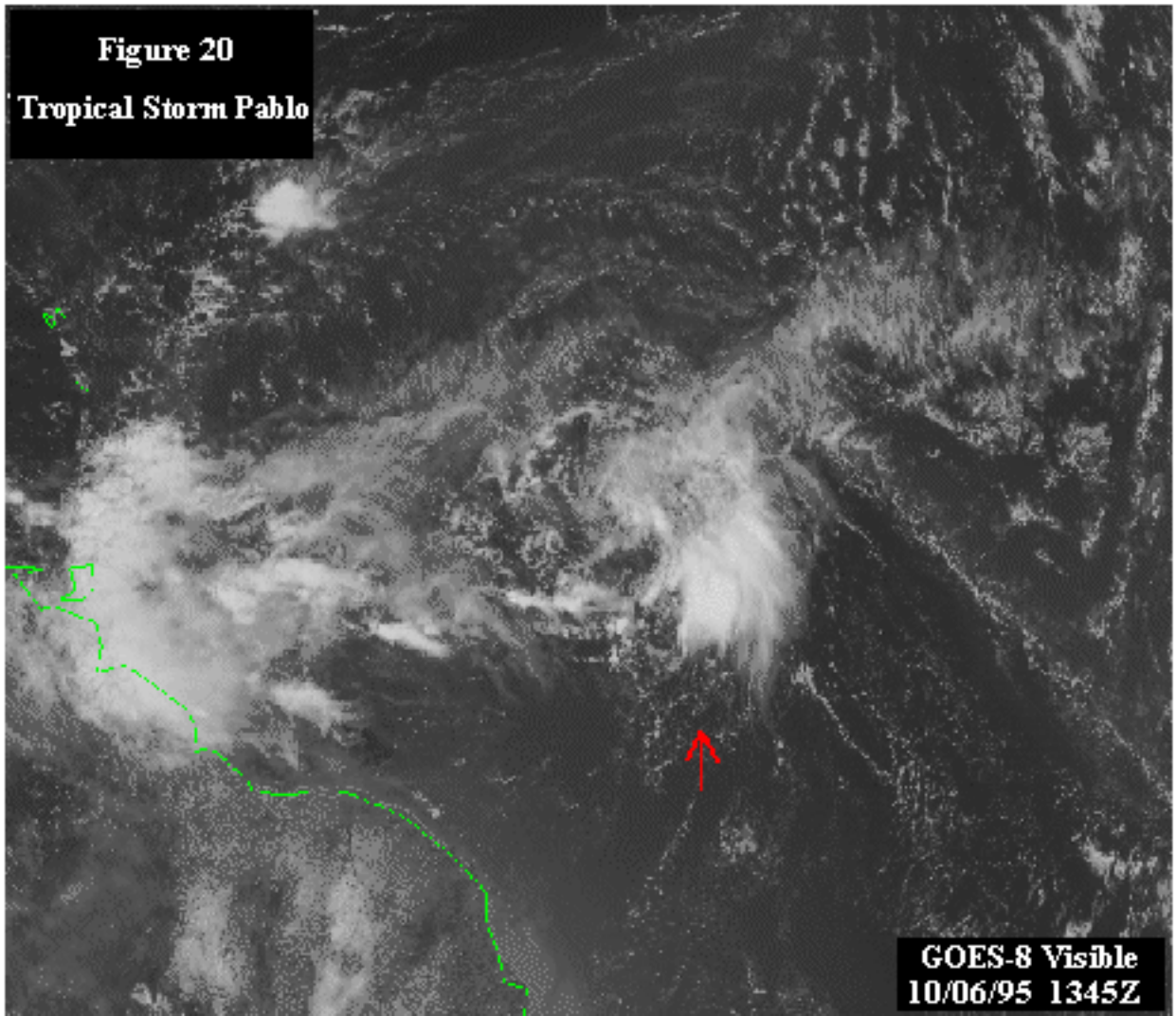
09/28/95 1145Z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Tropical Storm Pablo
GOES-8 Visible
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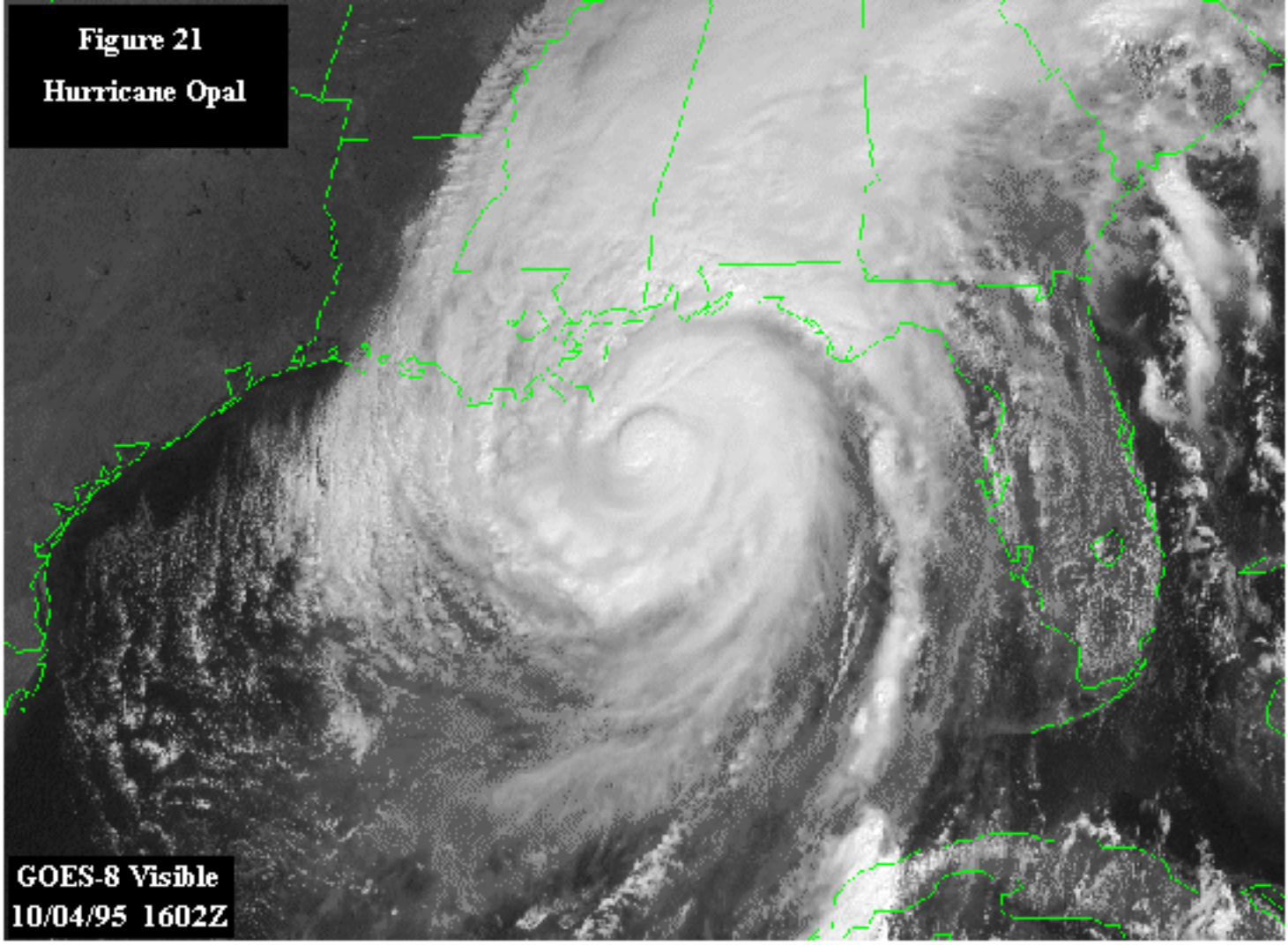
Figure 21
Hurricane Opal
GOES-8 Visible
10/04/95 1602Z

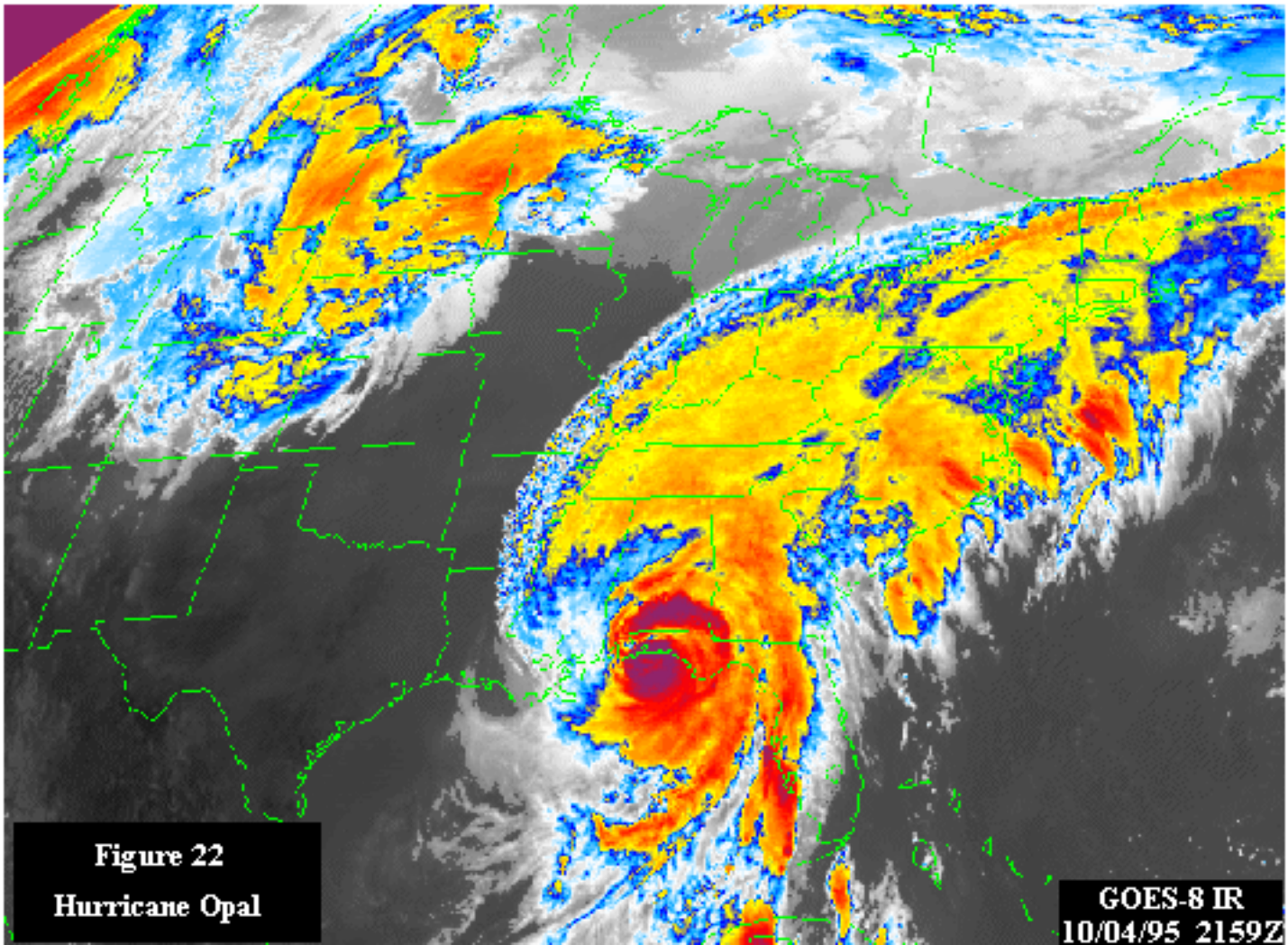
Figure 22
Hurricane Opal
GOES-8 IR
10/04/95 2159Z

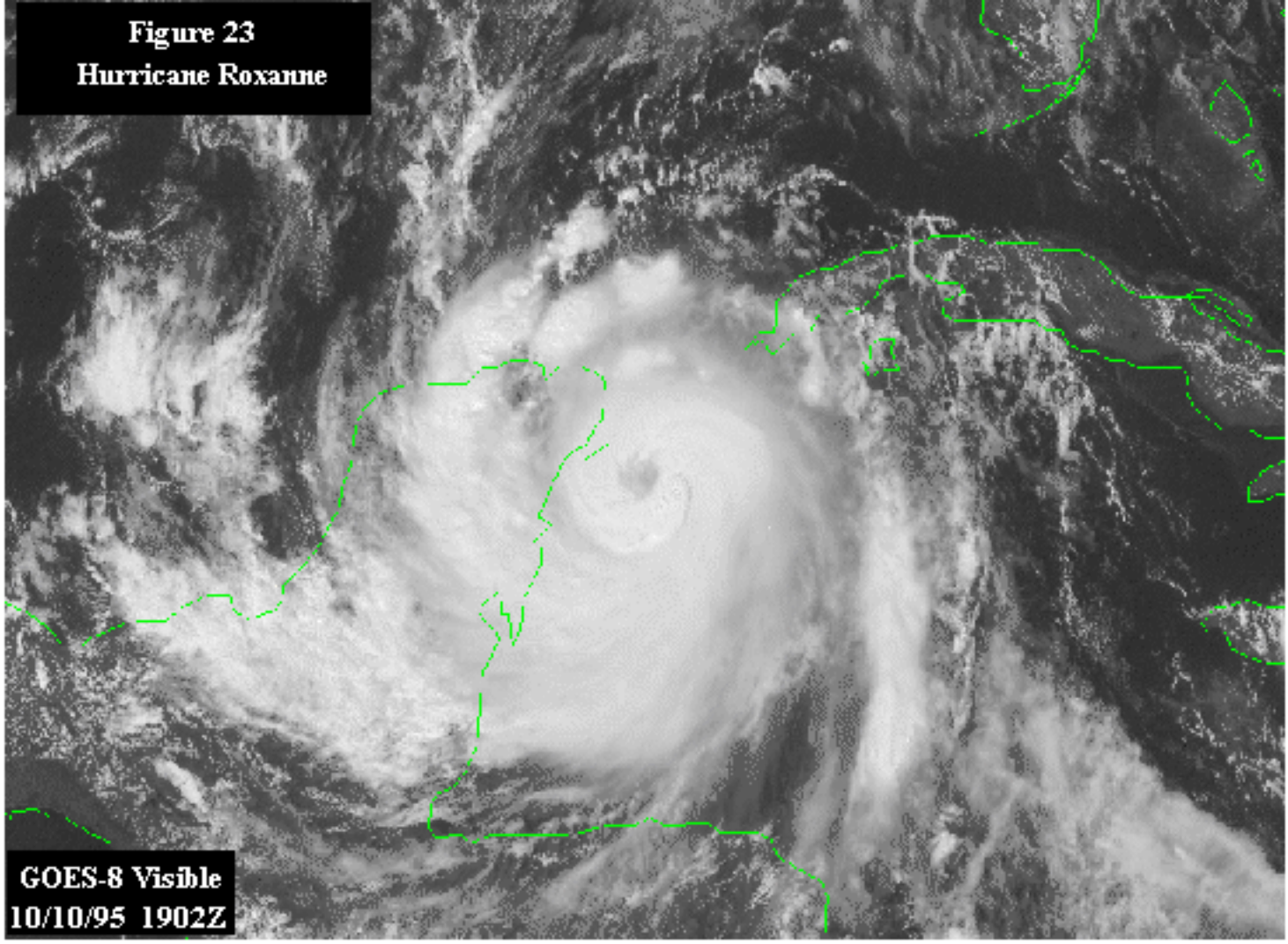
Figure 23
Hurricane Roxanne
GOES-8 Visible
10/10/95 1902Z

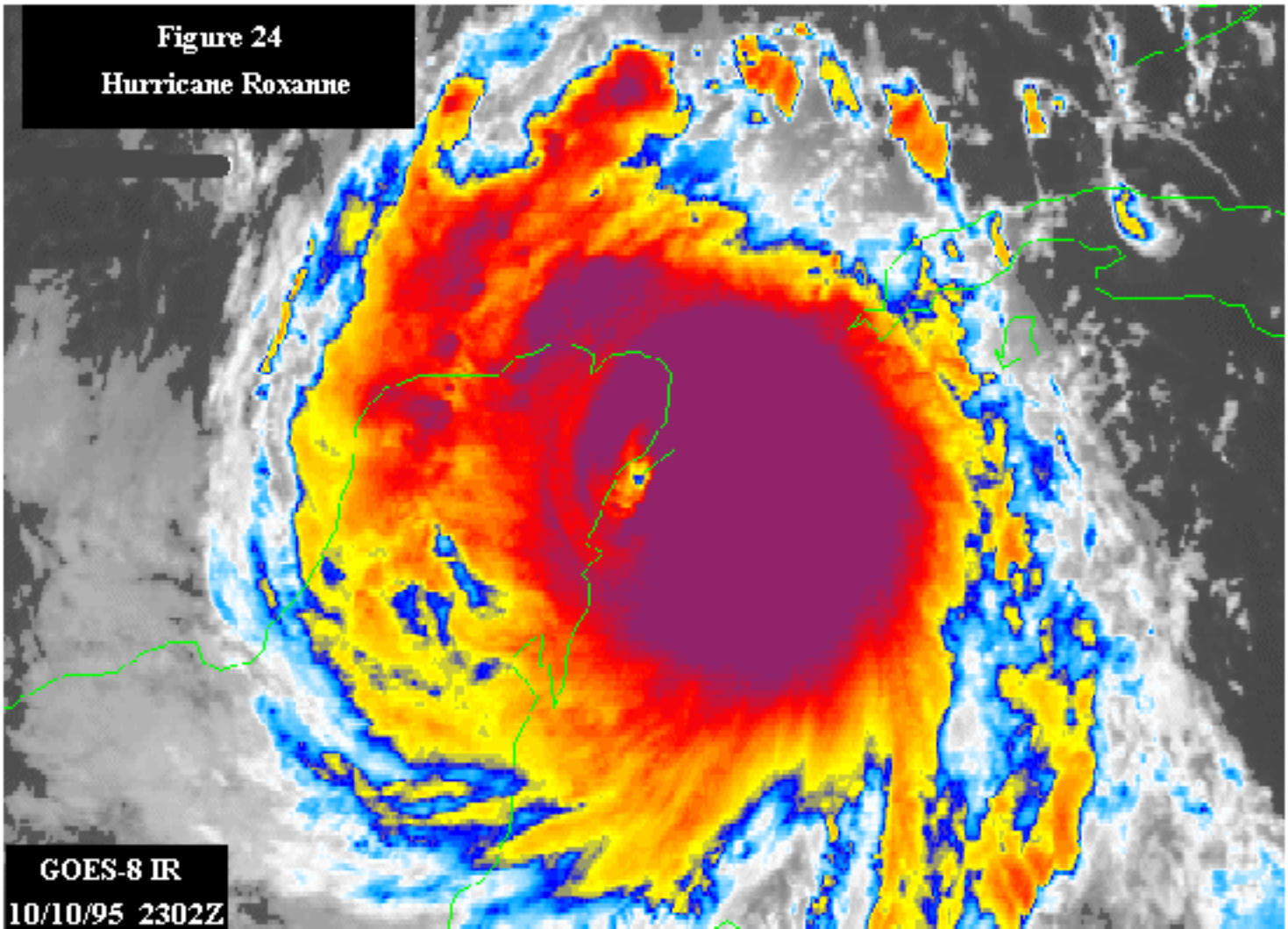
Figure 24
Hurricane Roxanne
GOES-8 IR
10/10/95 2302Z

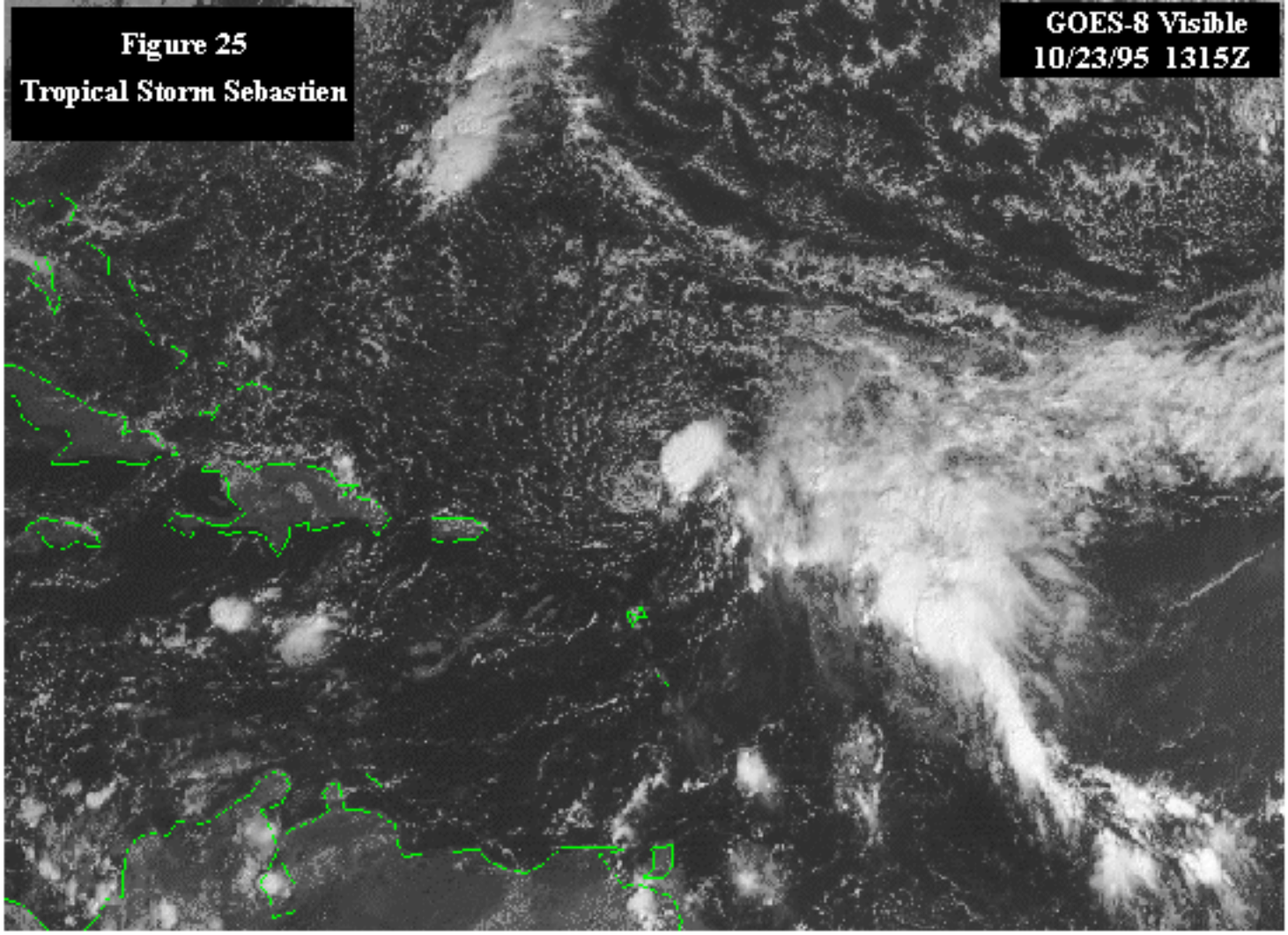

Figure 25
Tropical Storm Sebastien

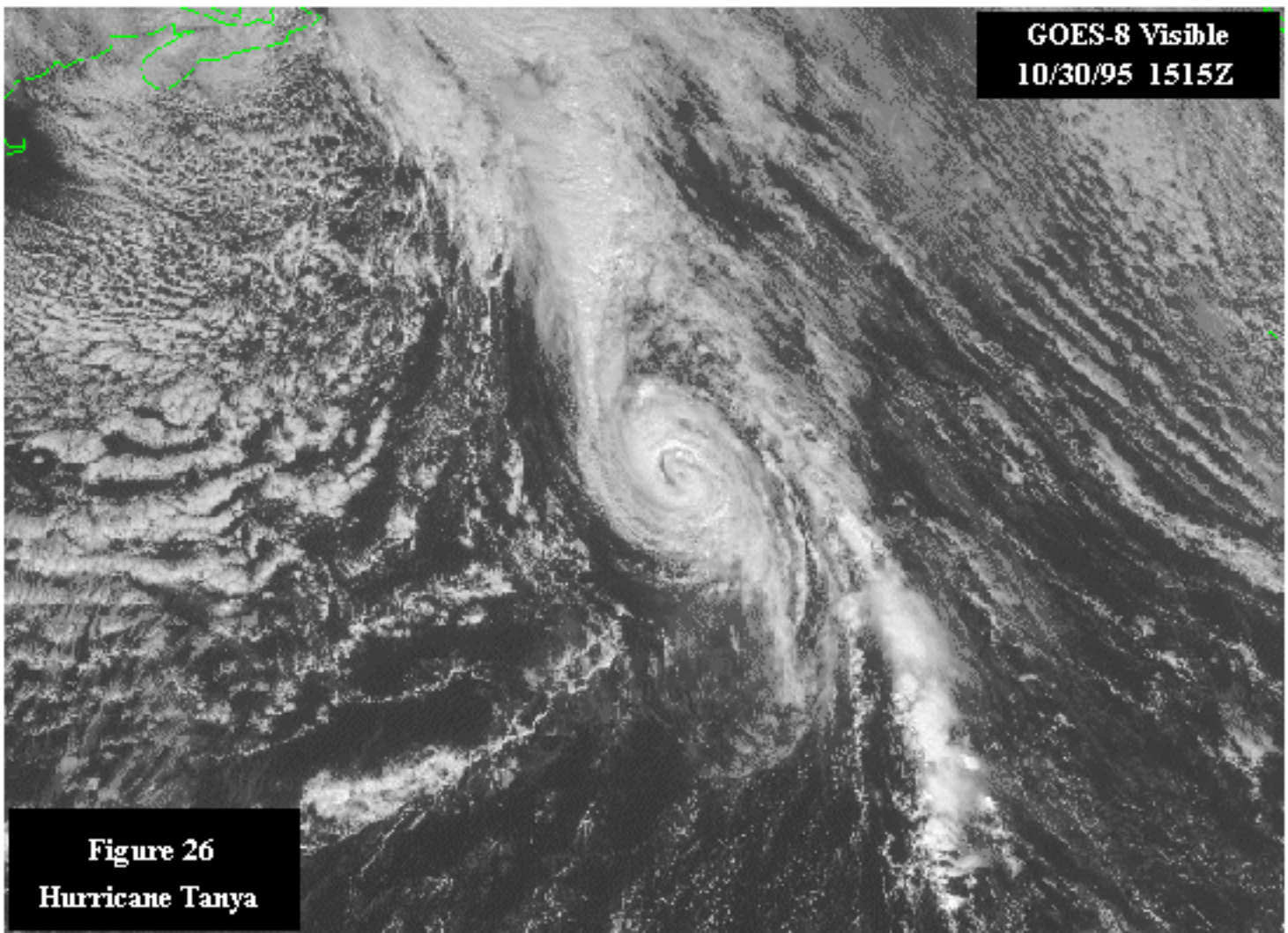

Figure 26
Hurricane Tanya

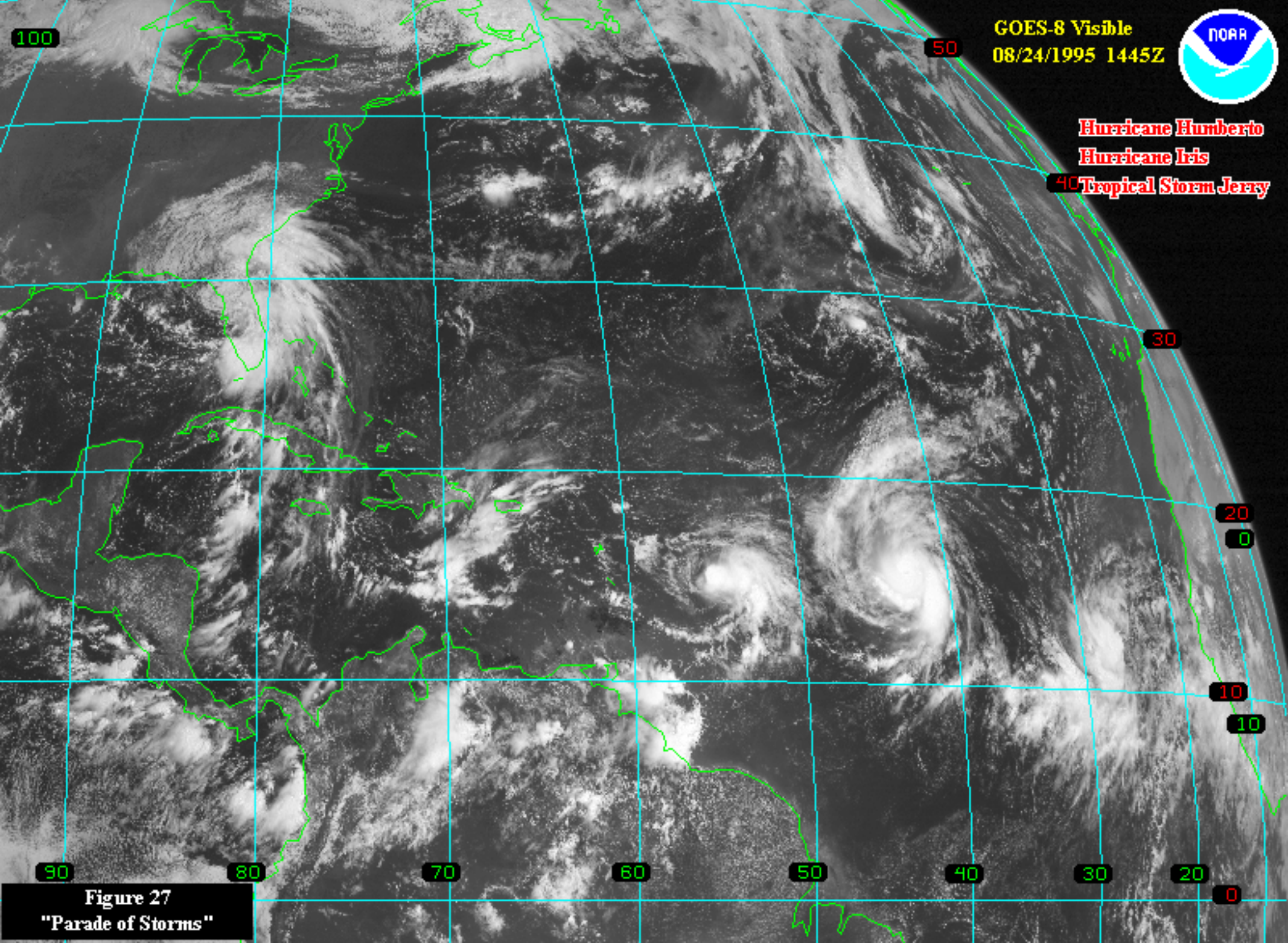

Figure 27
"Parade of Storms"

NATIONAL HURRICANE CENTER

ATLANTIC • CARIBBEAN • GULF OF MEXICO • HURRICANE TRACK CHART

1995 NUMBER	TYPE	NAME	DATE
1	H	ALLISON	JUN 03 - 06
2	T	BARRY	JUL 06 - 10
3	T	CHANTAL	JUL 12 - 20
4	T	DEAN	JUL 28 - AUG 02
5	H	ERIN	JUL 31 - AUG 06
6	H	FELIX	AUG 08 - 22
7	T	GABRIELLE	AUG 09 - 12
8	H	HUMBERTO	AUG 22 - SEP 01
9	H	IRIS	AUG 22 - SEP 04

1995 NUMBER	TYPE	NAME	DATE
10	T	JERRY	AUG 22 - 28
11	T	KAREN	AUG 26 - SEP 03
12	H	LUIS	AUG 27 - SEP 11
13	H	MARILYN	SEP 12 - 22
14	H	NOEL	SEP 26 - OCT 07
15	H	OPAL	SEP 27 - OCT 05
16	T	PABLO	OCT 04 - 06
17	H	ROXANNE	OCT 07 - 21
18	T	SEBASTIEN	OCT 20 - 25
19	H	TANYA	OCT 27 - NOV 01

Hurricane
Tropical Storm
Tropical Dep.
Extratropical
Position at 0000 UTC
21 Position/date at 1200 UTC
3 Tropical Cyclone Number

Lambert Conformal Conic true at 20° and 40° North

Figure 28

120° 115° 110° 105° 100° 95° 90° 85° 80° 75° 70° 65° 60° 55° 50° 45° 40° 35° 30° 25° 20° 15° 10° 5° West 0° East 5°

45° 40° 35° 30° 25° 20° 15° 10° 5° North 0° South

95° 90° 85° 80° 75° 70° 65° 60° 55° 50° 45° 40° 35° 30° 25°

12 Jan 96