The Atlantic Hurricane Database Reanalysis Project

9 November, 2015

14th International Workshop on Wave Hindcasting and Forecasting

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Supported by the NOAA Climate Program Office

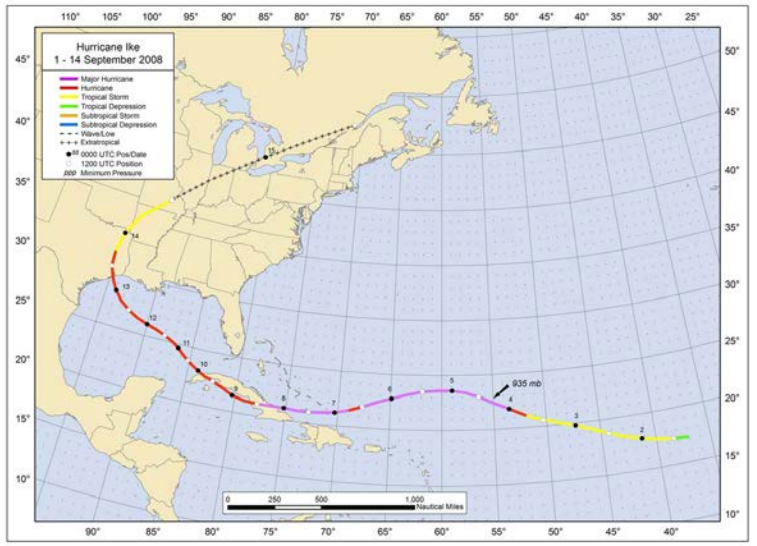
Acknowledgements: Andrew Hagen, Sandy Delgado, Brenden Moses, and Best Track Change Committee (Jack Beven – Chair, Richard Pasch, Eric Blake, Todd Kimberlain, Dave Roth, and Neal Dorst)

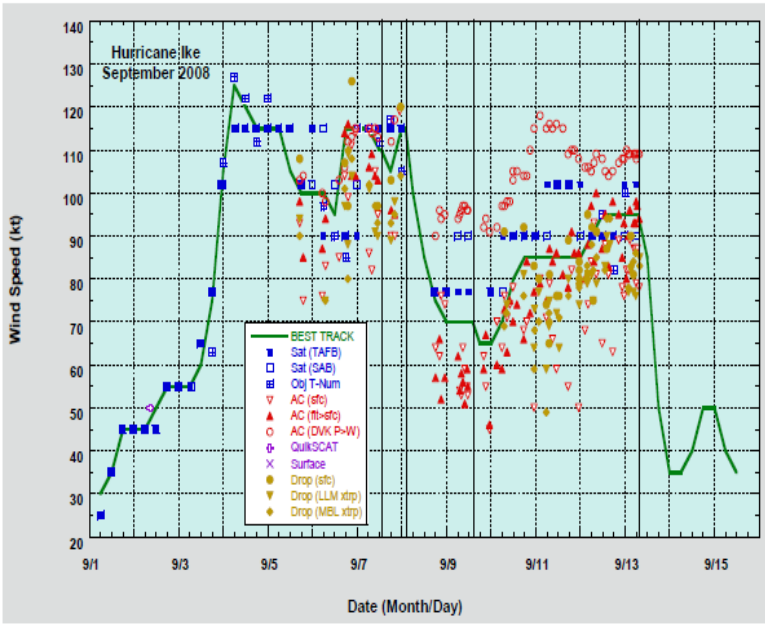
HURDAT

The National Hurricane Center maintains and updates annually the North Atlantic Basin's Hurricane Database (HURDAT)

HURDAT provides from 1851 to 2014 for all tropical storms, subtropical storms, and hurricanes every 6 hours:

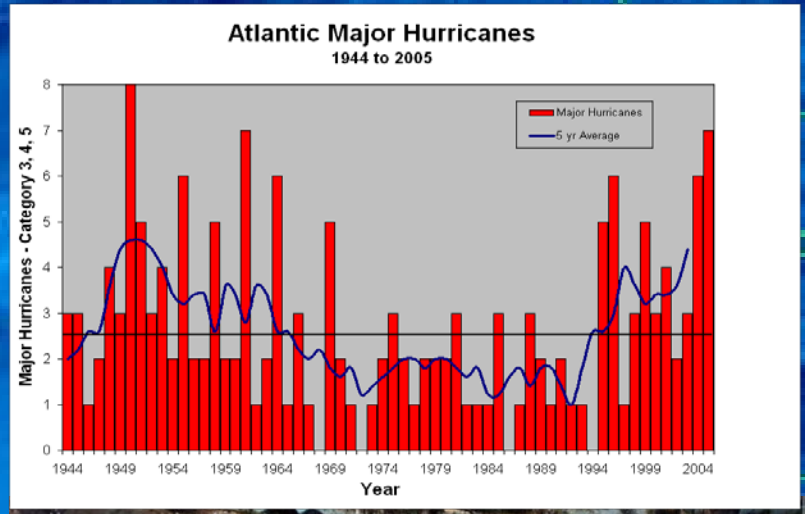
- **Positions** (to nearest 0.1 degree latitude/longitude)
- **Intensity** (1 min surface winds to nearest 10 kt from 1851-1885, 5 kt from 1886 onward)
- **Central pressure** (to nearest 1 mb, when observed)
- **34, 50, and 64 kt wind radii maximum extent** since 2004 (by quadrant, to nearest 10 nmi)

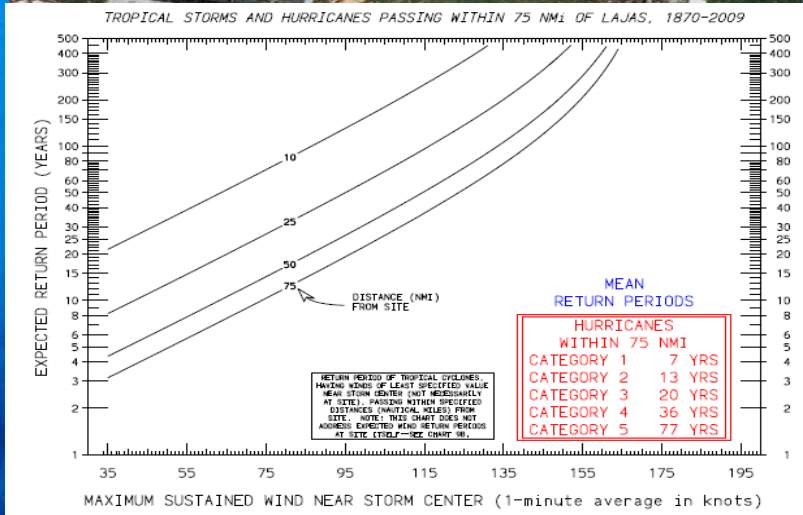




HURDAT applications:

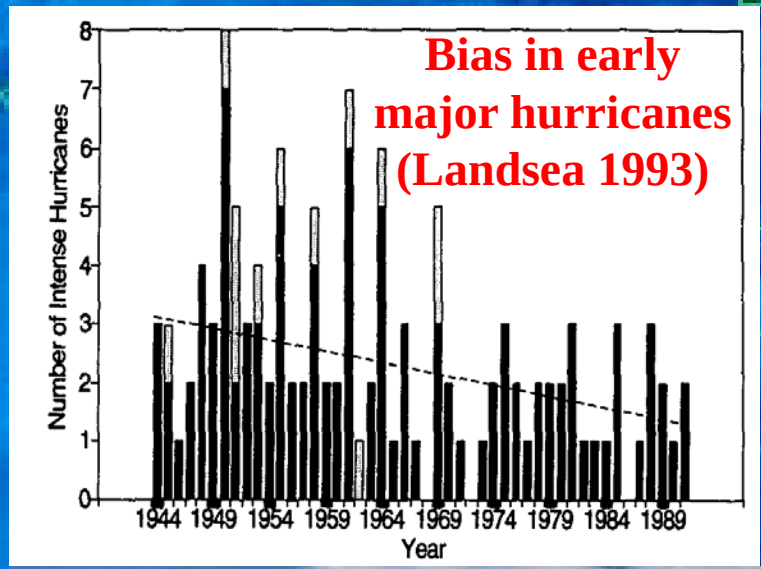
- Validation of official and model predictions
- Climate trend assessment – long term trends, seasonal forecasts, etc.
- Building code standards and insurance rates for coastal communities
- Risk assessment for emergency managers (recurrence intervals)





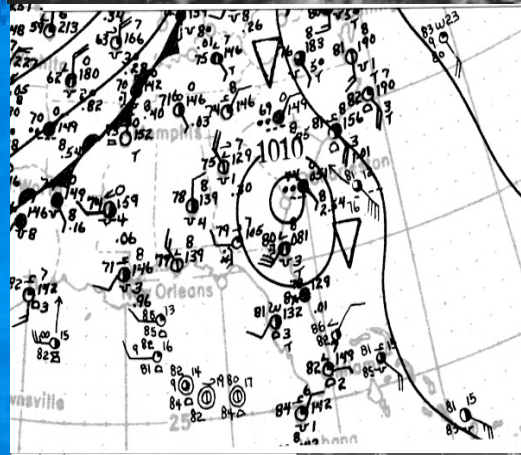
Why revise HURDAT?

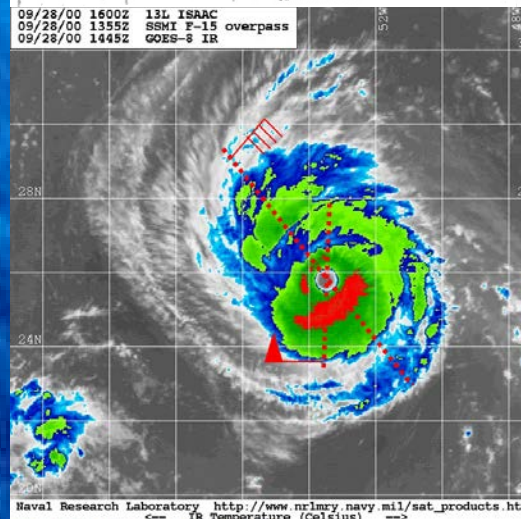
- HURDAT contains many systematic and random errors
  - 1938 Hurricane: Cat 3 at landfall, but 85kts at last offshore position
- "Missing storms"
- Lack of exact hurricane landfall parameters
- Advances in the understanding of hurricanes and analysis techniques



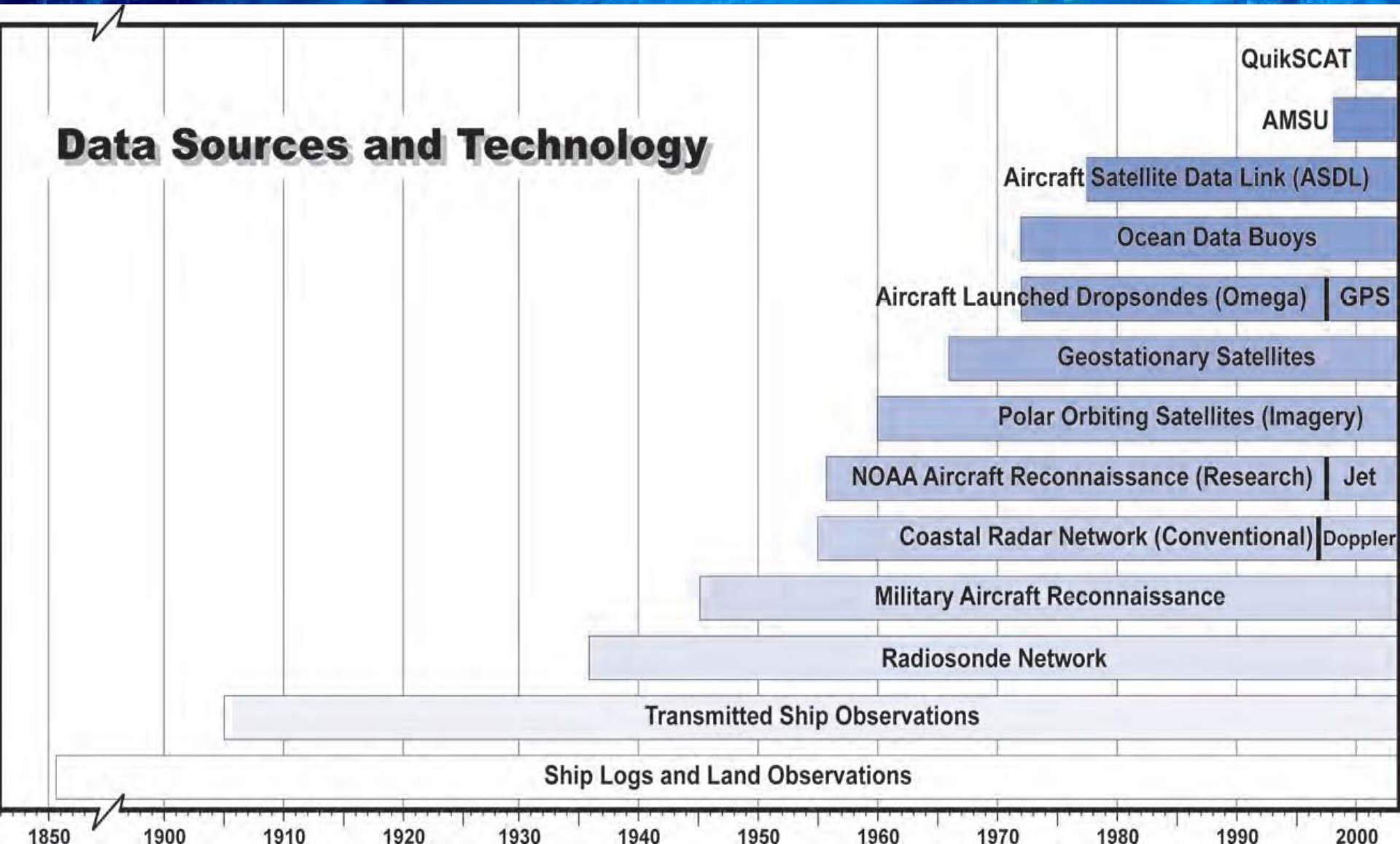
Reanalysis Steps

1) Obtain all available raw data into a single database
2) Conduct synoptic analysis four times daily
3) Determine track
4) Determine intensity
5) Document revisions (metadata file)

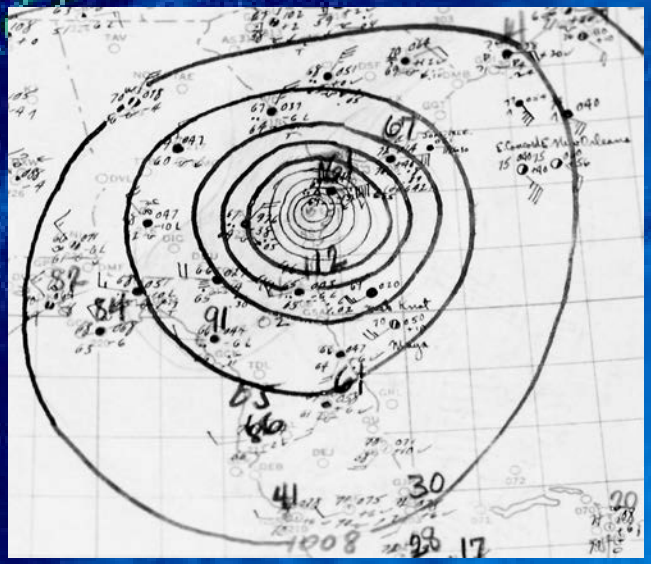




Observation Capabilities: Huge Improvements over Time

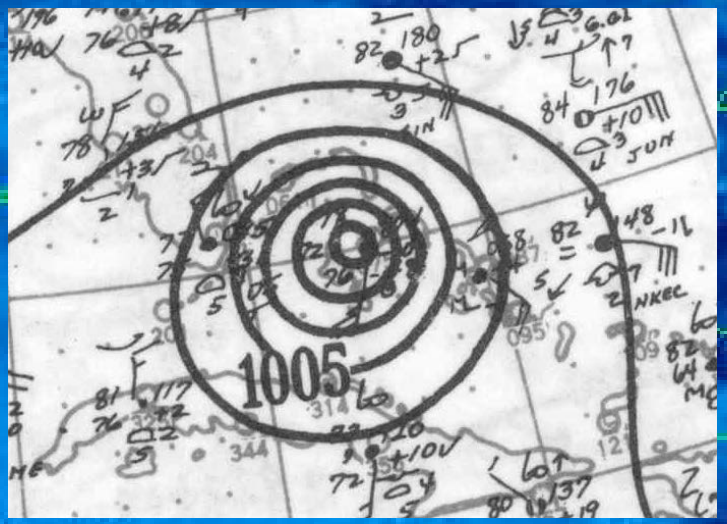


Surface Observations

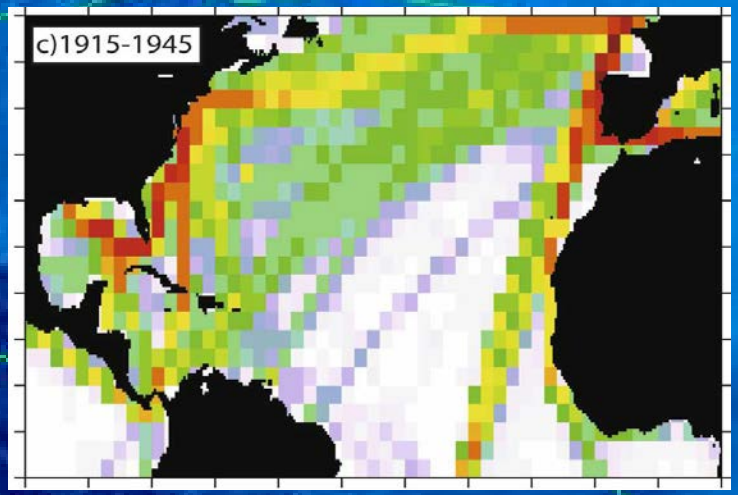


NHC Microfilm Maps

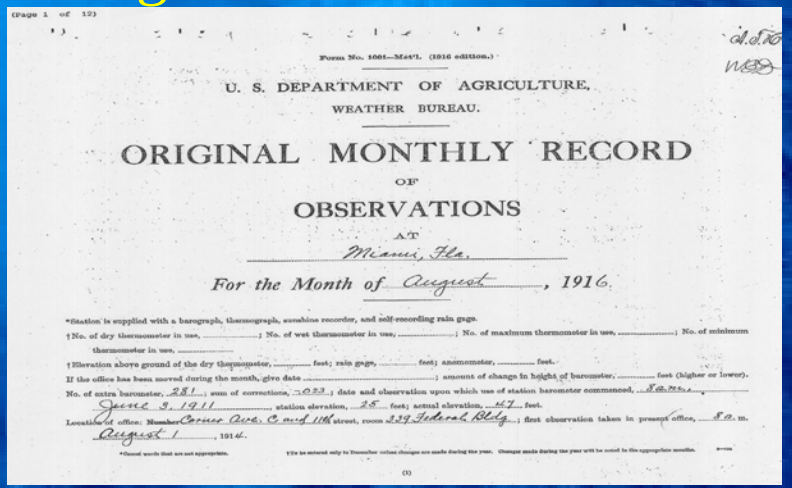
Historical Weather Maps



Comprehensive Ocean-Atmosphere Dataset (COADS)



U.S. and Caribbean Original Station Records



(Page 1 of 12)

Form No. 1001—M&V. (1916 edition.)

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU.

ORIGINAL MONTHLY RECORD
OF
OBSERVATIONS
AT
Miami, Fla.
For the Month of August, 1916.

*Station is supplied with a barograph, thermograph, sunshine recorder, and self-recording rain gage.
†No. of dry thermometer in use, ; No. of wet thermometer in use, ; No. of maximum thermometer in use, ; No. of minimum thermometer in use, .
†Elevation above ground of the dry thermometer, feet; rain gage, feet; anemometer, feet.
If the office has been moved during the month, give date ; amount of change in height of barometer, feet (higher or lower).
No. of extra barometer, 281; sum of corrections, -.023; date and observation upon which use of station barometer commenced, 8 a.m.
June 3, 1911, station elevation, 25 feet; actual elevation, 47 feet.
Location of office: Number Corner Ave. C and 11th street, room 339 Federal Bldg.; first observation taken in present office, 8 a. m.
August 1, 1914.
*Cancel words that are not appropriate.
†To be entered only in December unless changes are made during the year. Changes made during the year will be noted in the appropriate months.

First Hurricane Flights - July 27th, 1943

HEADQUARTERS
ARMY AIR FORCES INSTRUCTORS' SCHOOL (INSTRUMENT PILOT)
Office of the Commanding Officer
Bryan, Texas

19 August 1943

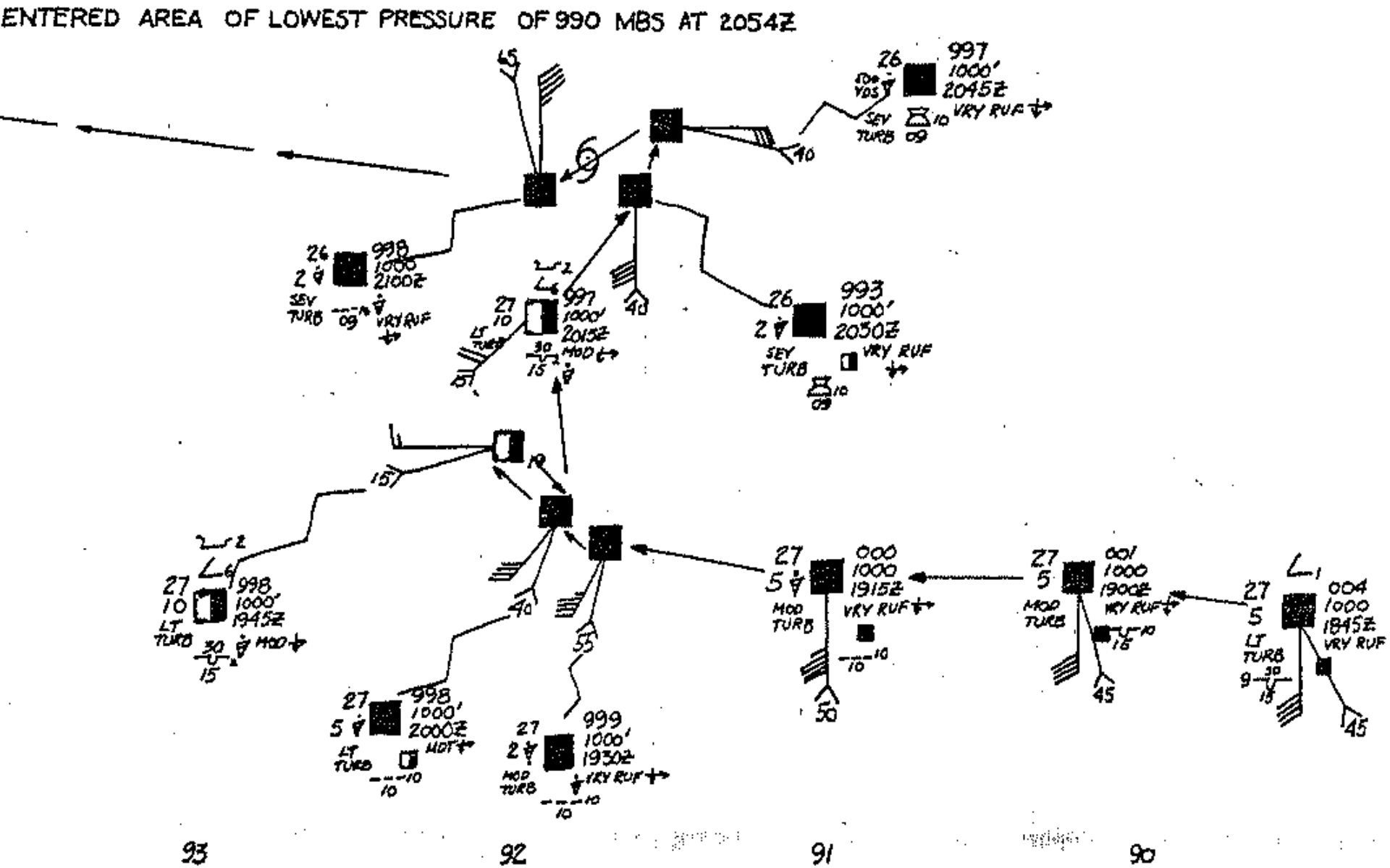
FLIGHT THROUGH A TROPICAL HURRICANE

BY JOSEPH B. DUCKWORTH, COLONEL, AIR CORPS

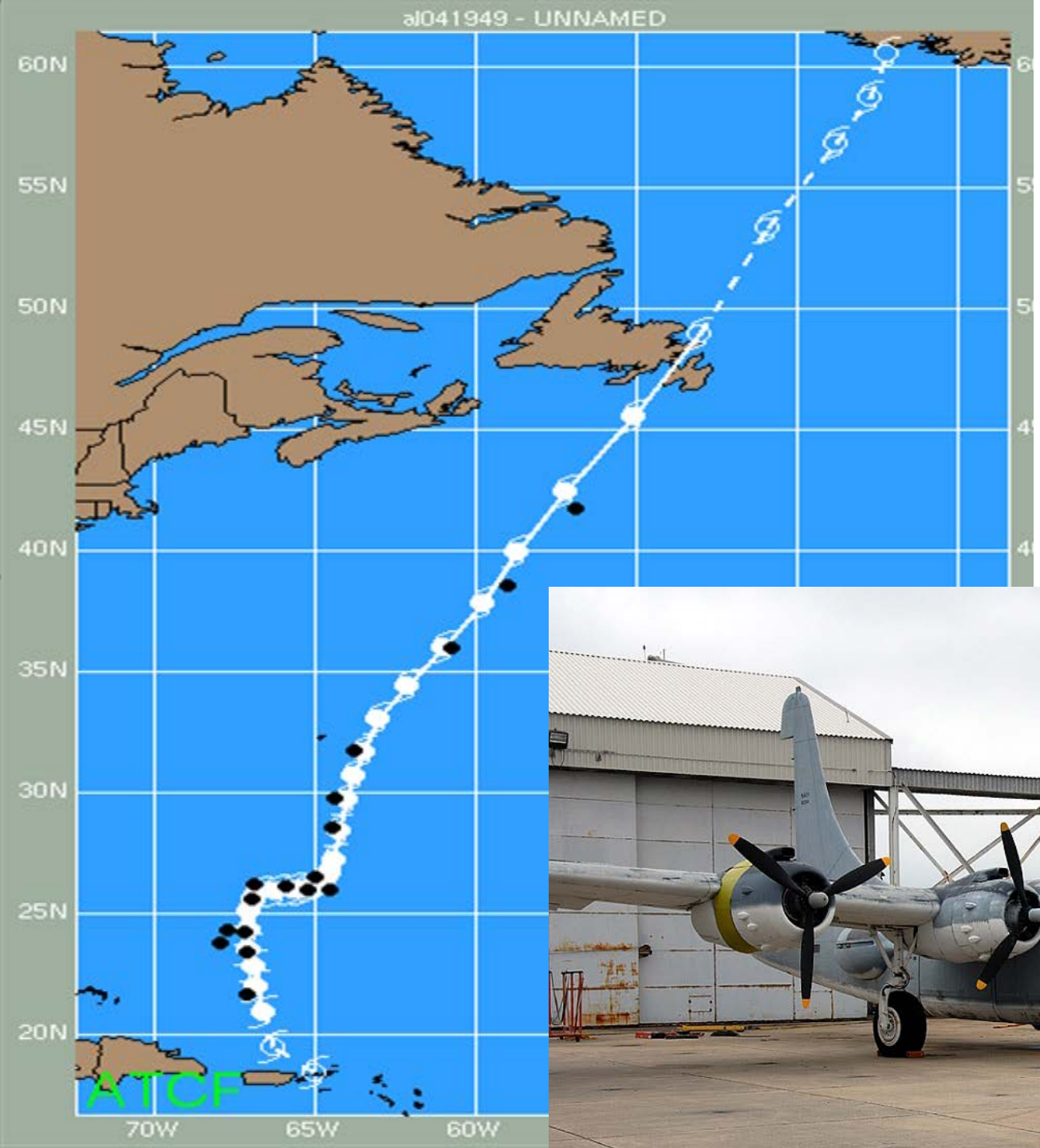
During the afternoon and evening of July 27, 1943, a tropical hurricane struck Galveston and Houston, Texas from the Gulf of Mexico.

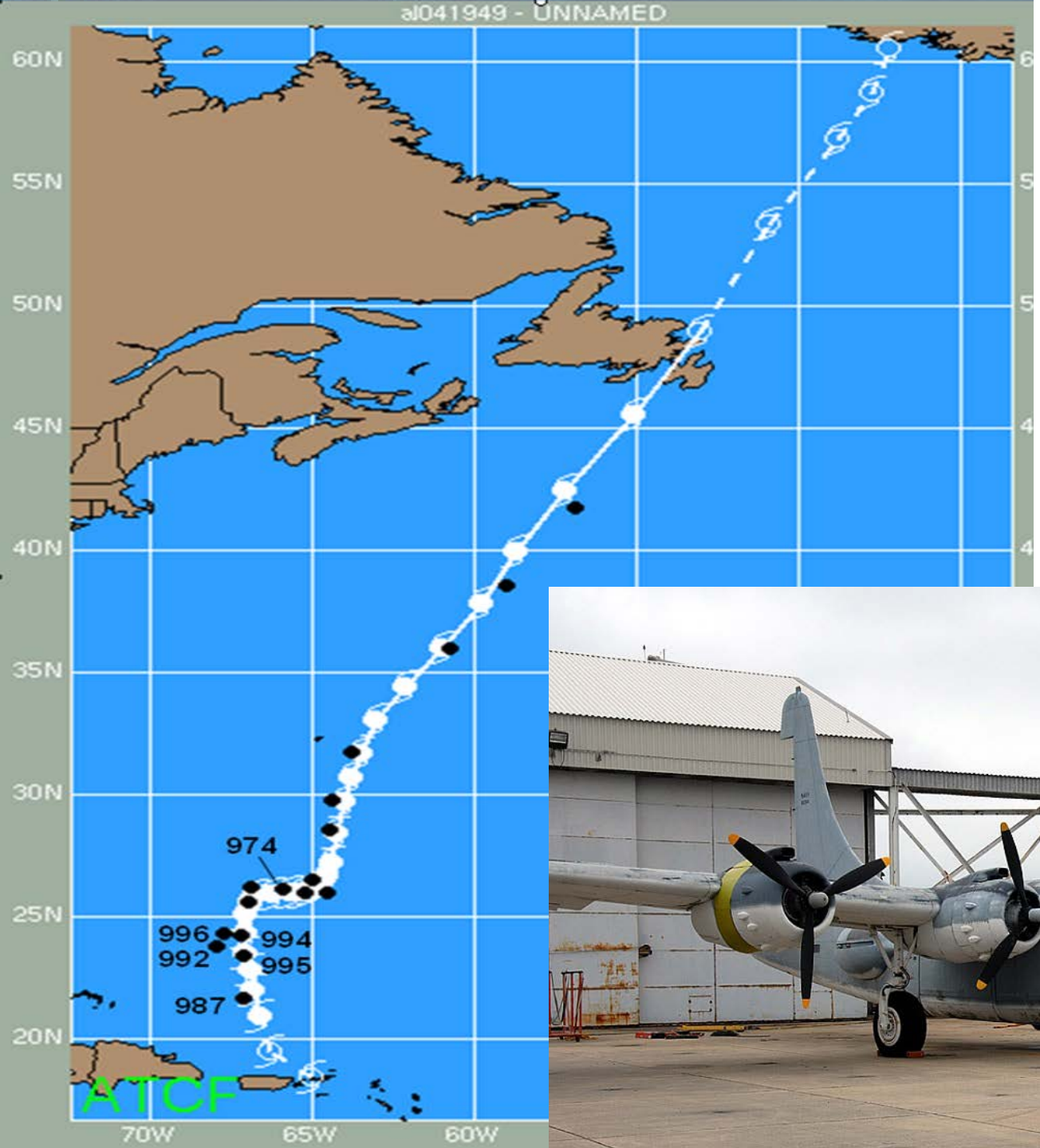
Between the hour of 14:00 and 19:00 two experimental trips were made (without landing, of course) in an AT-6 airplane, around and through the center of the hurricane. The observer on the first trip was 2nd Lt. Ralph M. O'Hair, navigator, and on the second trip 1st Lt. Wm. H. Jones-Burdick, a pilot-weather officer. Both trips were made at differing altitudes between 4000 ft. and 9000 ft.

Aircraft Reconnaissance Penetration: 1948 Storm 5



Hurricane Aircraft Reconnaissance in late 1940s and early 1950s: U.S. Navy's PB4Y2



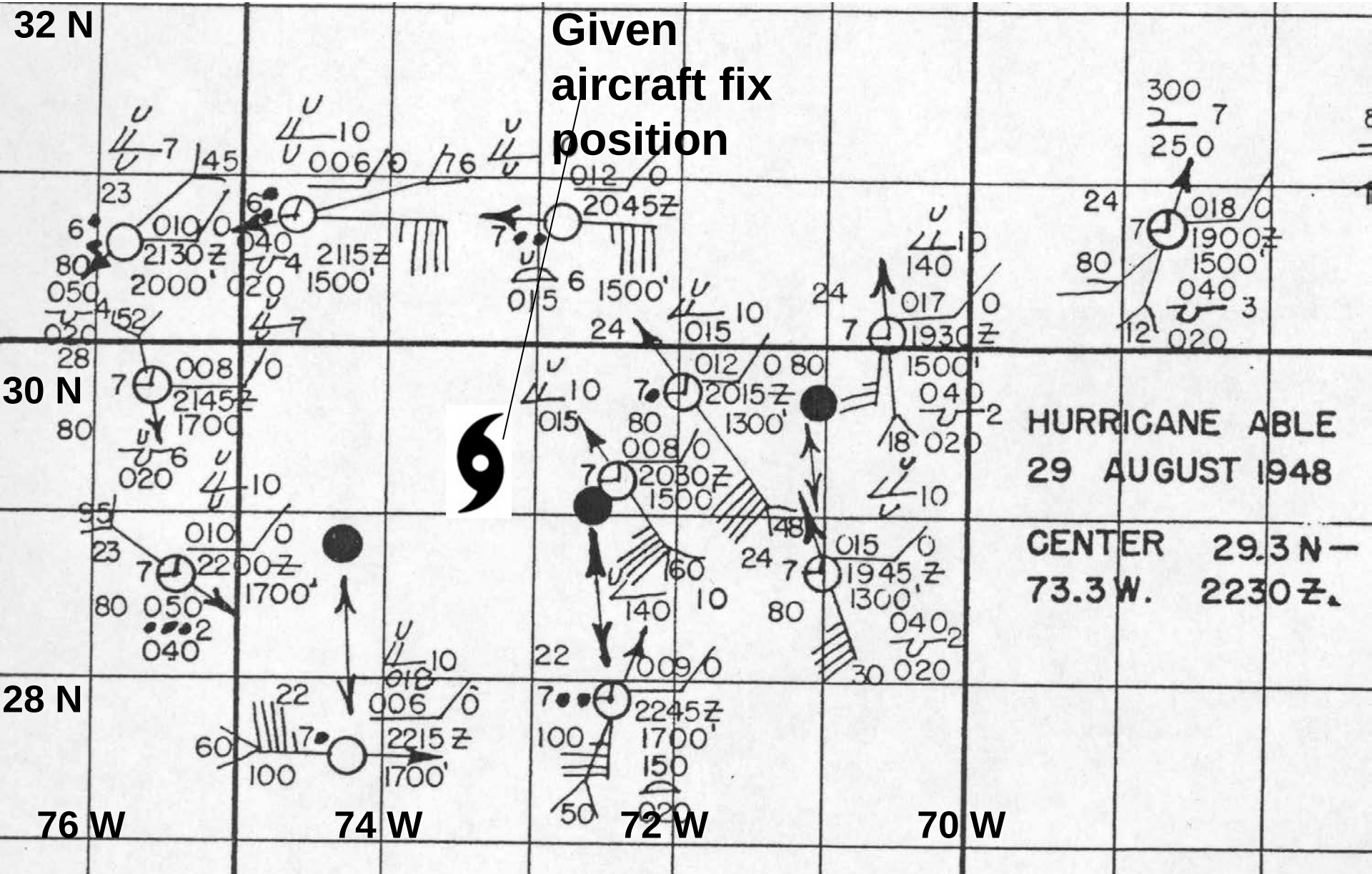


U.S. Navy's PB4Y2:

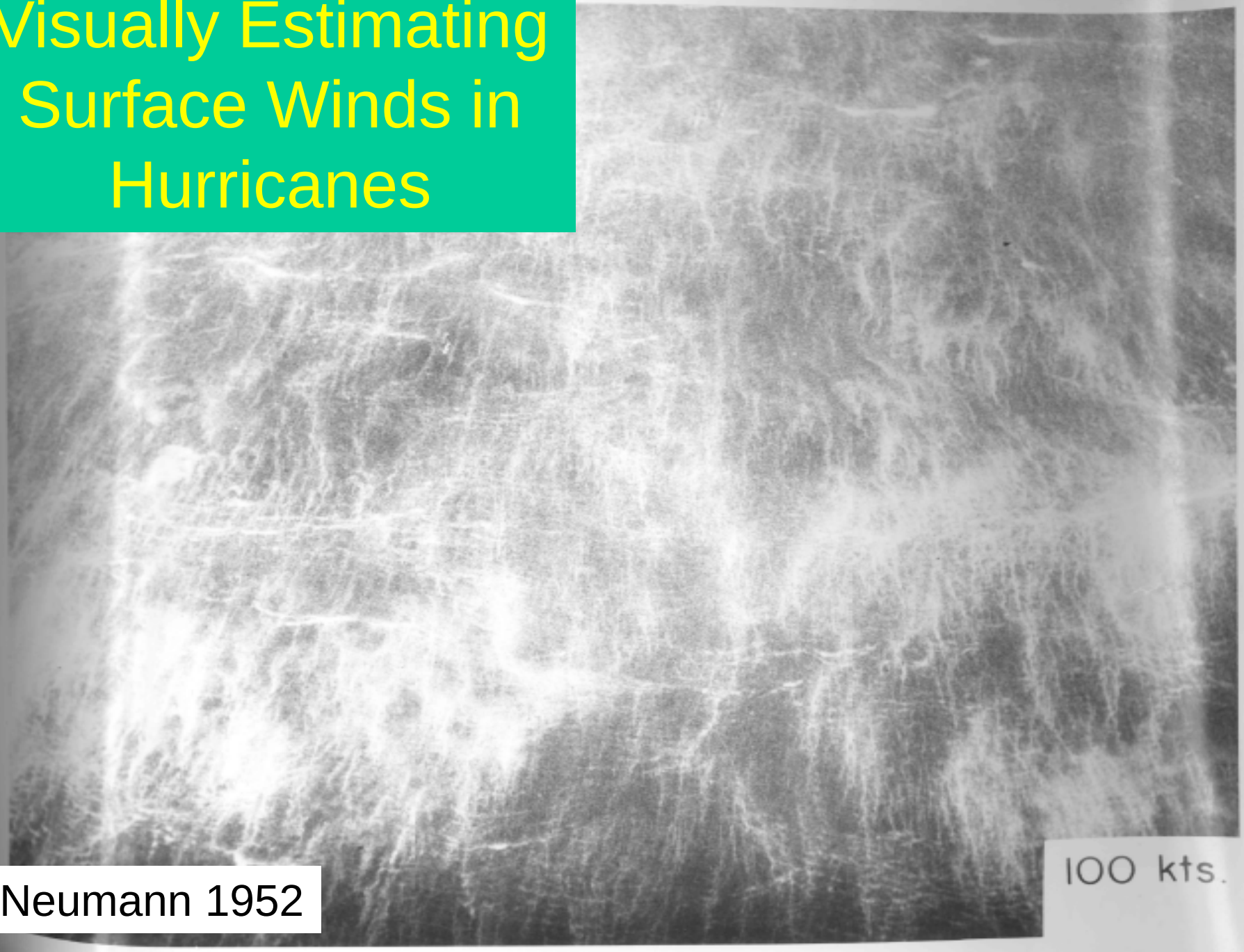
- No night flights
- No central pressure for major hurricanes

Flight track 1948 Storm 3 – August 29th

Circumnavigation - typical technique for intense hurricanes



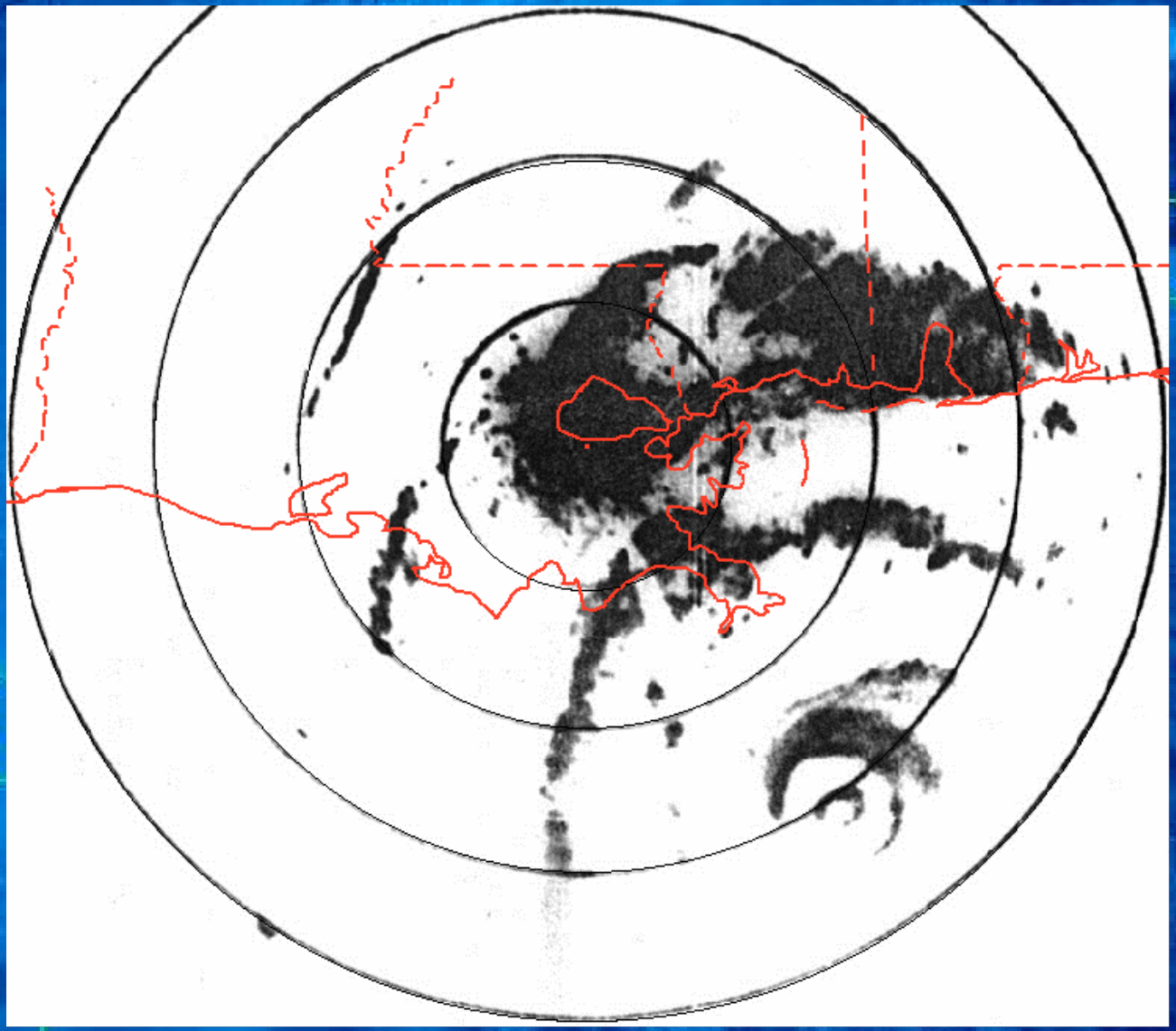
Visually Estimating Surface Winds in Hurricanes



Neumann 1952

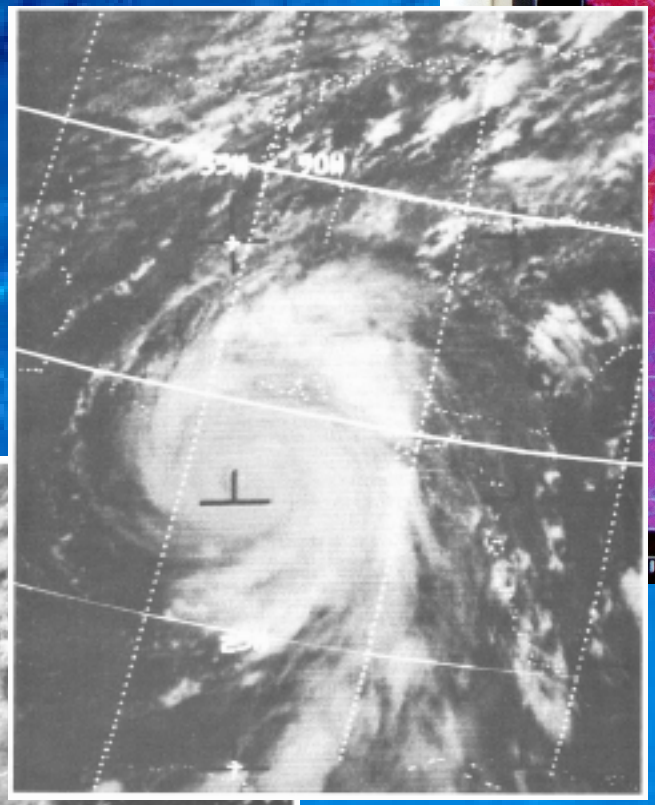
Camille Radar loop from New Orleans

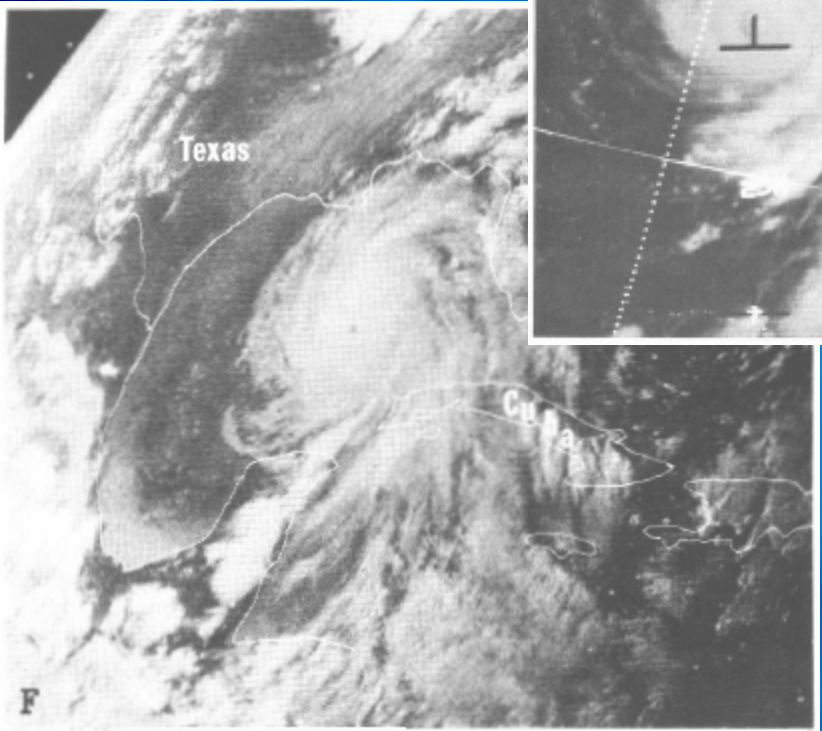
- Images were scaled and overlaid onto map with range rings
- ~100 images were processed
- 17/1630Z (first within range) to 18/0600Z (after landfall) every 10 minutes
- Outer eyewall had become predominant by time of landfall

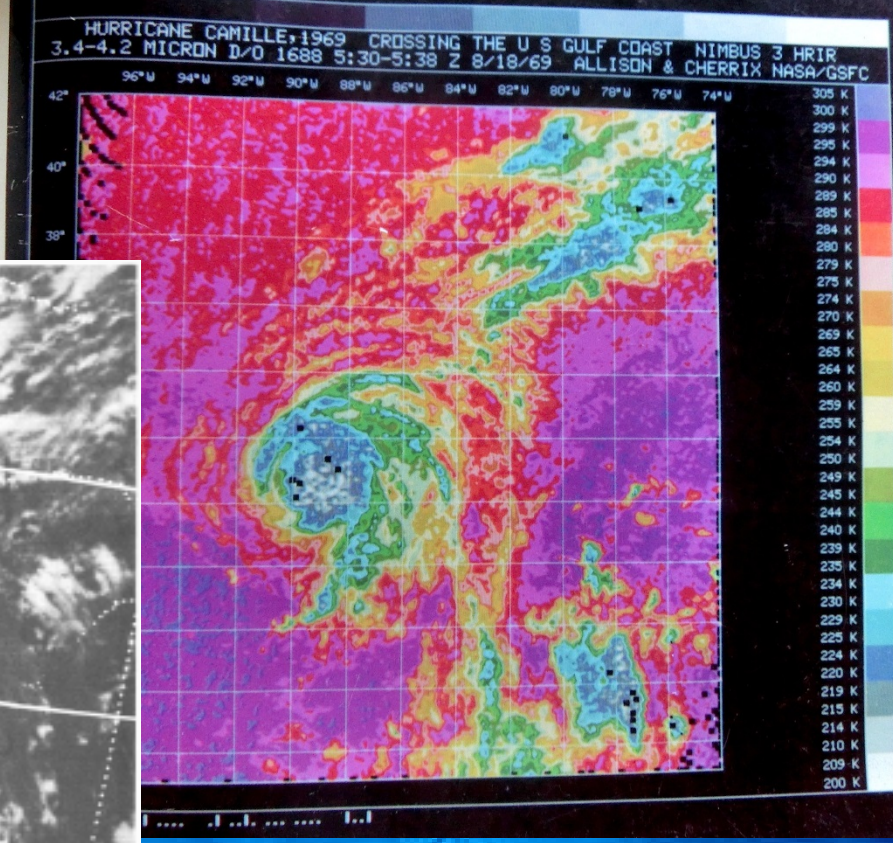


Camille Satellite Imagery

ATS







Nimbus-3

ESSA-8,9

Reanalysis Products

Raw Data

9-Aug	15Z	1018	5	SE	81	82	SHIP	202	604	COA	
9-Aug	1530Z						RECON	322	641	WALLET	Radar fix
9-Aug	16Z					81	SHIP	382	631	COA	30771
9-Aug	16Z					77	SHIP	315	580	COA	31420
9-Aug	~16Z	975			Kindley Air Force Base, Bermuda			324	647	WALLET	advisories
9-Aug	~16Z		66		Kindley Air Force Base, Bermuda			324	647	WALLET	Gusts to 85 kt - advisories
9-Aug	18Z	1012	5	N	84	81	SHIP	340	748	COA	
9-Aug	18Z	1010	5	SSW	81	75	SHIP	373	748	COA	1212

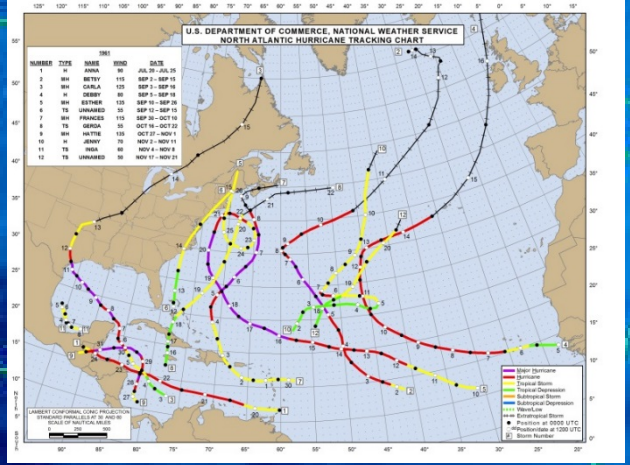
"Best Track" Data

```
42685 08/03*149 508   80   996*
42685 08/03*149 511   65   996*
```

Metadata

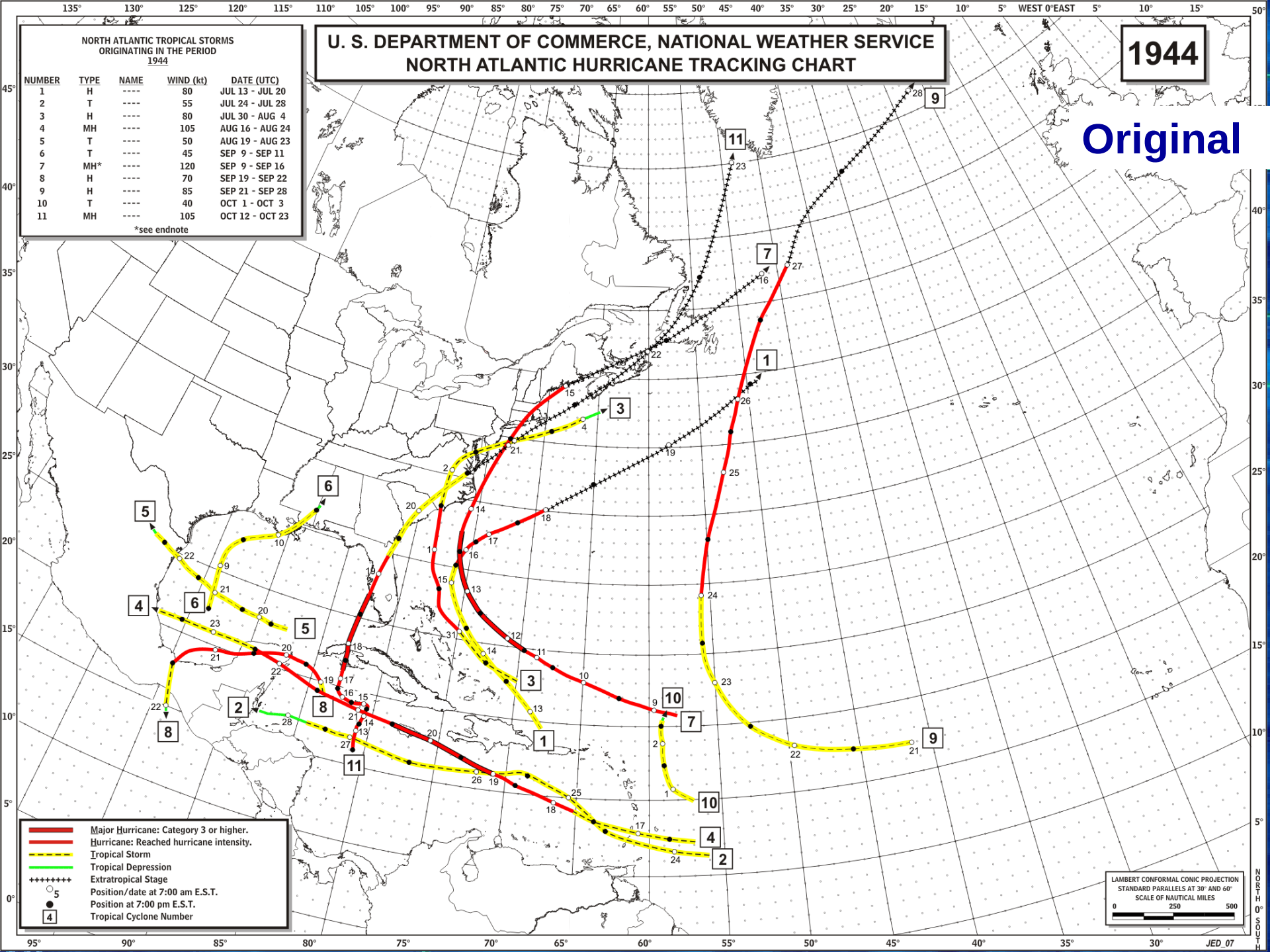
Arlene made landfall in Bermuda around 1530Z on the 9th as a small, rapidly-moving and intensifying hurricane. The Kindley Air Force Base, located in the northeastern part of the island, measured maximum sustained winds of 66 kt and with gusts to 85 kt around 16Z. A central pressure measured in Bermuda was 975 mb, which suggests maximum surface winds of 79 kt from the north of 25N pressure-wind relationship. Based on a forward speed of about 31 kt and small RMW, an intensity of 95 kt is selected at the time of landfall.

Track Maps



Comments by/Replies to Best Track Change Committee

Hurricane Baker, 1950. The reductions in intensity on 21 August appear justified. However, they leave a discontinuous jump to a 90 kt intensity at 0000 UTC 22 August Please re-examine this intensity to see if it should be lowered, explaining how the Antigua data was taken into account.


U. S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
NORTH ATLANTIC HURRICANE TRACKING CHART
1944
Original
NORTH ATLANTIC TROPICAL STORMS
ORIGINATING IN THE PERIOD
1944
NUMBER TYPE NAME WIND (kt) DATE (UTC)
1 H ---- 80 JUL 13 - JUL 20
2 T ---- 55 JUL 24 - JUL 28
3 H ---- 80 JUL 30 - AUG 4
4 MH ---- 105 AUG 16 - AUG 24
5 T ---- 50 AUG 19 - AUG 23
6 T ---- 45 SEP 9 - SEP 11
7 MH* ---- 120 SEP 9 - SEP 16
8 H ---- 70 SEP 19 - SEP 22
9 H ---- 85 SEP 21 - SEP 28
10 T ---- 40 OCT 1 - OCT 3
11 MH ---- 105 OCT 12 - OCT 23
*see endnote
Major Hurricane: Category 3 or higher.
Hurricane: Reached hurricane intensity.
Tropical Storm
Tropical Depression
Extratropical Stage
Position/date at 7:00 am E.S.T.
Position at 7:00 pm E.S.T.
Tropical Cyclone Number
LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS AT 30° AND 60°
SCALE OF NAUTICAL MILES
0 250 500
JED_07

U. S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
NORTH ATLANTIC HURRICANE TRACKING CHART

1944

Revised

NORTH ATLANTIC TROPICAL STORMS ORIGINATING IN THE PERIOD 1944

NUMBER	TYPE	NAME	WIND (kt)	DATE (UTC)
1	H	----	65	JUL 13 - JUL 20
2	T	----	55	JUL 24 - JUL 28
3	H	----	65	JUL 30 - AUG 4
4	MH	----	105	AUG 16 - AUG 24
5	T	----	50	AUG 18 - AUG 23
6	T	----	50	SEP 9 - SEP 11
7	MH	----	120	SEP 9 - SEP 16
8	H	----	70	SEP 19 - SEP 22
9	H	----	85	SEP 21 - SEP 28
10	T	----	45	SEP 30 - OCT 3
11	T	----	40	SEP 30 - OCT 3
12	H	----	70	OCT 11 - OCT 17
13	MH	----	120	OCT 12 - OCT 24
14	H	----	60	NOV 1 - NOV 3

Major Hurricane : Category 3 or higher.
Hurricane : Reached hurricane intensity.
Tropical Storm
Tropical Depression
Extratropical Stage
Position/date at 7:00 am E.S.T.
Position at 7:00 pm E.S.T.
Tropical Cyclone Number

LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS AT 20° AND 60°
SCALE OF NAUTICAL MILES
0 250 500

JED_07

HURDAT Intensity Error Estimates

Year	US Landfalling	Open ocean with aircraft, central pressures	Open ocean with aircraft, no central pressures	Open ocean without aircraft/landfall unpopulated coast
1851-1885	15 kt	N/A	N/A	25 kt
1886-1943	12 kt	N/A	N/A	20 kt
1944-1953	11 kt	13 kt	15 kt	20 kt
1954-1963	10 kt	12 kt	15 kt	20 kt
Late 1990s	10 kt	12 kt	N/A	15 kt
Late 2000s	9 kt	10 kt	N/A	12 kt

Atlantic Hurricane Database Re-Analysis Project

http://www.aoml.noaa.gov/hrd/data_sub/re_anal.html

1) 1851 through 1955 (plus Camille/Andrew) changes accepted and officially adopted by NHC Best Track Change Committee

2) 1956-1965 have been preliminarily reanalyzed

3) Remainder of 20th Century will be reanalyzed

RE-ANALYSES NEED TO BE CONDUCTED GLOBALLY!!!

"Florida's Hurricane History"

The Atlantic Hurricane Database Reanalysis Project

9 November, 2015

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Supported by the NOAA Climate Program Office

Acknowledgements: Andrew Hagen, Sandy Delgado, Brenden Moses, and Best Track Change Committee (Jack Beven – Chair, Richard Pasch, Eric Blake, Todd Kimberlain, Dave Roth, and Neal Dorst)

HURDAT Position Error Estimates

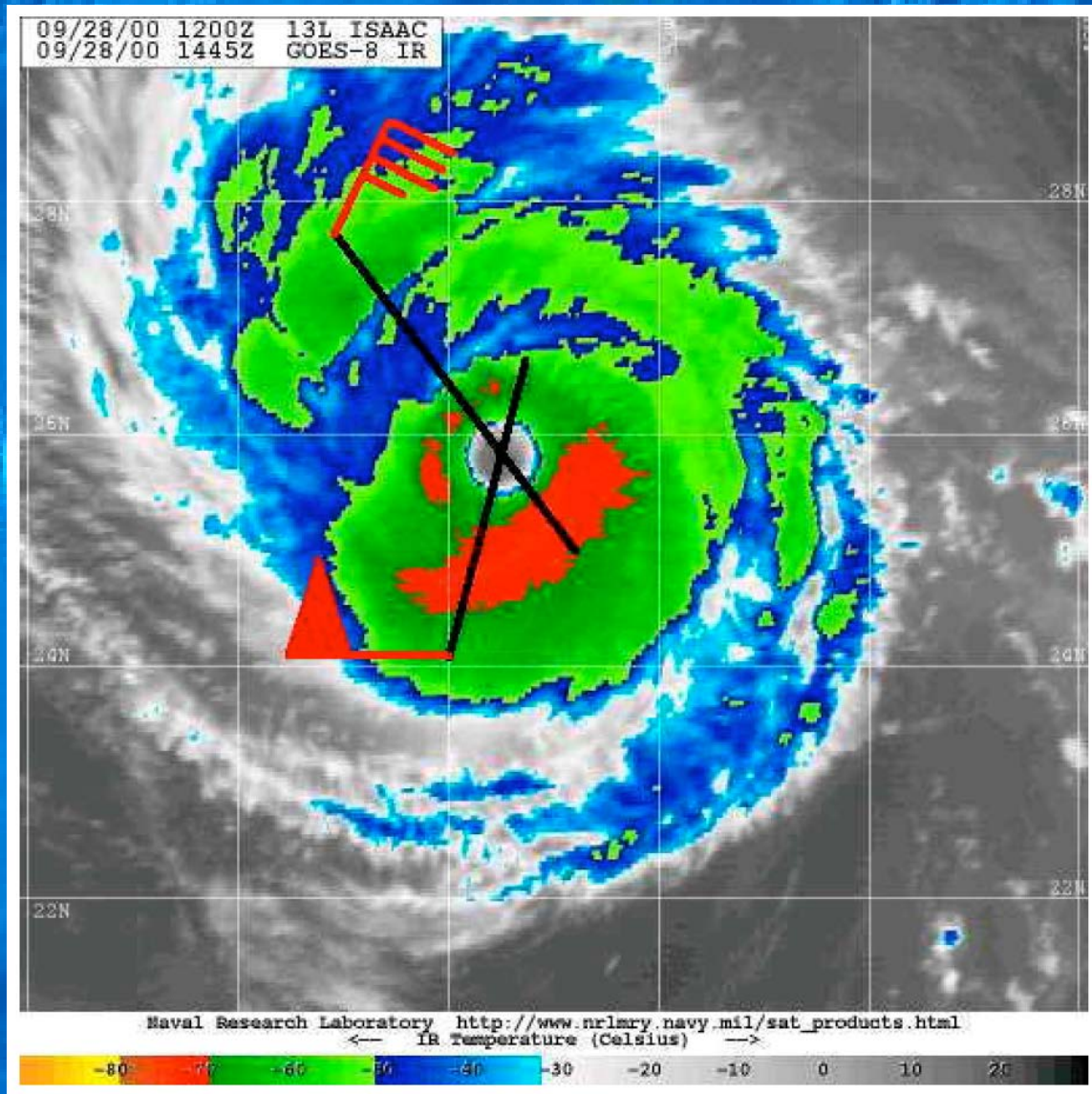
Year	US Landfalling	Open ocean with aircraft	Open ocean without aircraft/landfall unpopulated coast
1851-1885	60 nm	N/A	120 nm
1886-1943	60 nm	N/A	100 nm
1944-1953	20 nm	35 nm	80 nm
1954-1963	15 nm	30 nm	60 nm
Late 1990s	12 nm	12 nm	25 nm
Late 2000s	12 nm	12 nm	25 nm

HURDAT Intensity Bias Estimates

Year	US Landfalling	Open ocean with aircraft, central pressures	Open ocean with aircraft, no central pressures	Open ocean without aircraft/landfall unpopulated coast
1851-1885	0 kt	N/A	N/A	-15 kt
1886-1943	0 kt	N/A	N/A	-10 kt
1944-1963	0 kt	0 kt	+5 to -10 kt	-10 kt
Late 1990s-2000s	0 kt	0 kt	N/A	0 kt

Track analysis methodology

- Ship and coastal observations allow for triangulation to obtain approximate center;
- If there is a lack of data, significant changes are not implemented



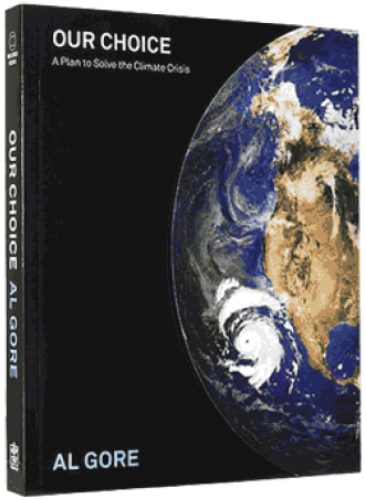
Intensity analysis tools

- Ship, coastal stations, aircraft reconnaissance data
- Brown et al. (2006) pressure-wind relationships
- Vickery et al. (2000) climatological RMW values
- Kaplan and DeMaria (1995) inland decay model
- Schloemer (1954) equation
  - Calculates central pressure given a peripheral pressure measurement
- Ho et al. (1987) inland pressure decay model
  - Estimates landfall central pressure based on a post-landfall central pressure measurement
- Neumann model from Schwerdt et al. (1979)
  - Calculates extent of hurricane force winds
- Franklin et al. (2003) flight-level to sfc wind

Hurricanes and Global Warming

Opinion piece by Christopher W. Landsea[1]
November 2011

Video of this presentation



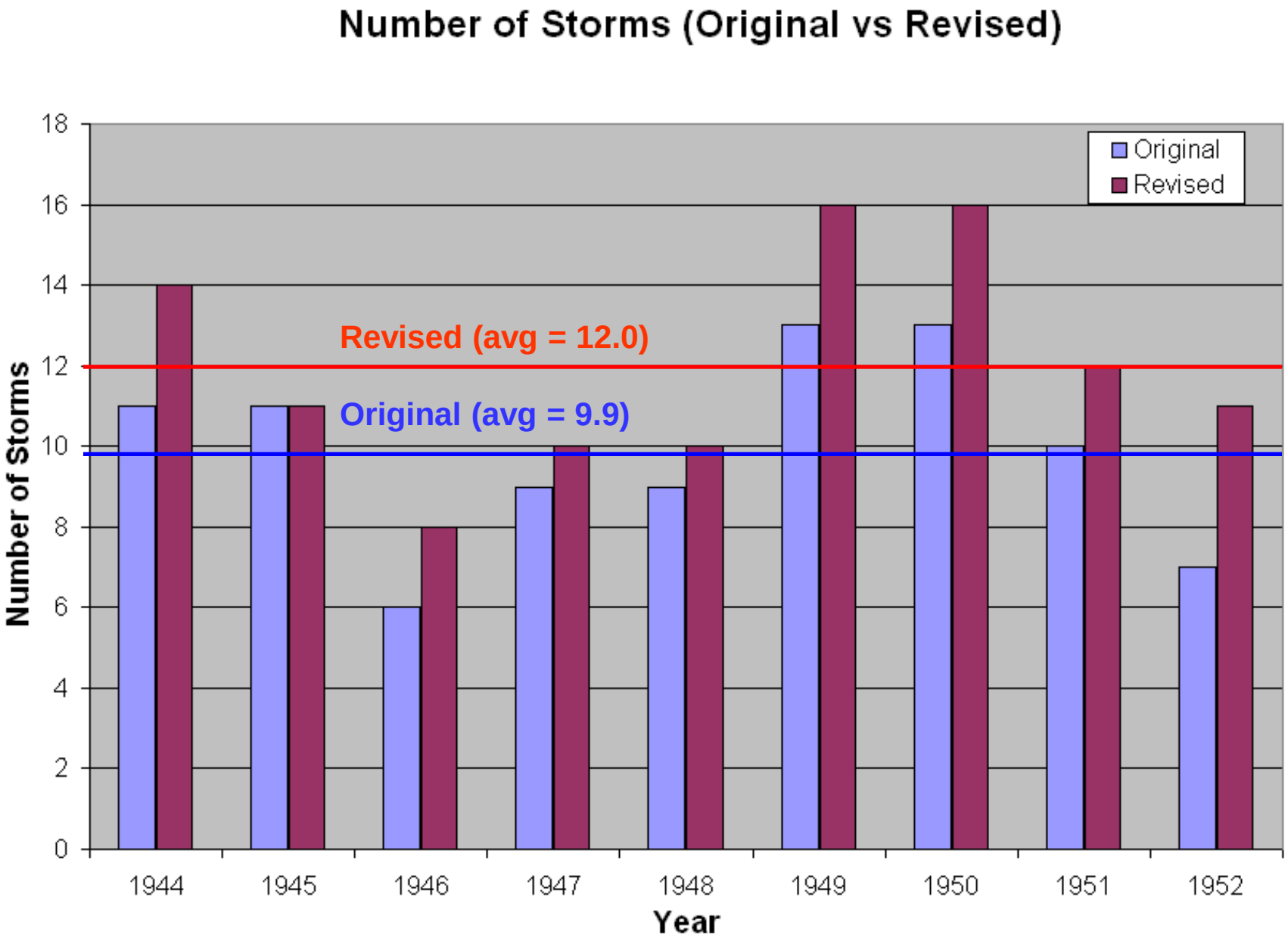
Hurricanes as the Poster-Child for Global Warming

Hurricanes have been depicted as the literal poster-child of the harmful impacts of global warming. Without argument, hurricanes (which also include storms known as "typhoons" in the Northwest Pacific and "severe tropical cyclones" in the Indian and Southwest Pacific) are extremely destructive and often responsible for the deaths of hundreds and occasionally thousands of people. As an example, Hurricane Katrina was responsible for the death of ~1200 and about $108 billion in damages.[2] The before and after pictures of the home of David and Kimberly King of Waveland, Mississippi show the incredible power of that hurricane's storm surge and winds.

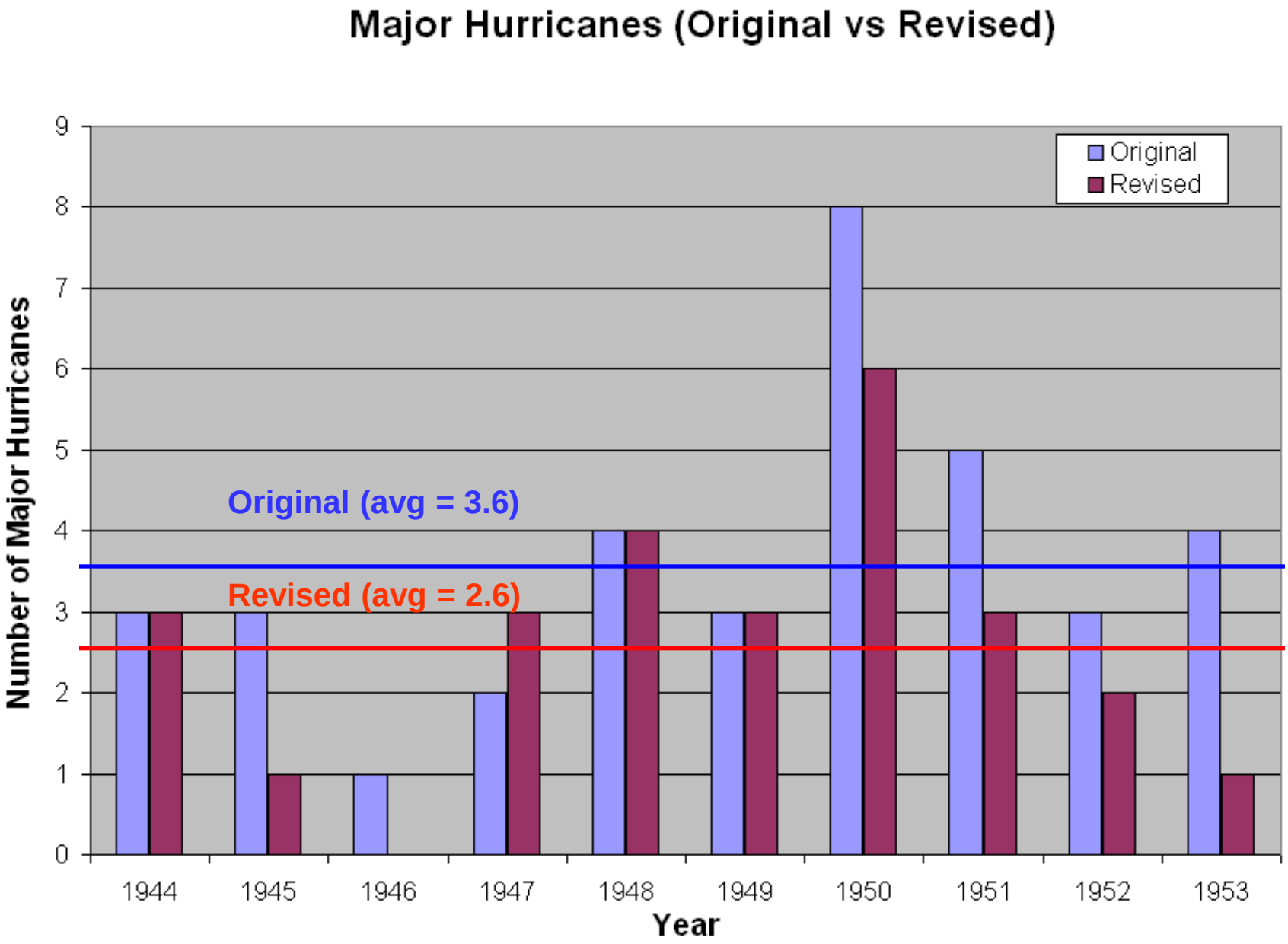
Opinion Piece on Hurricanes and Global Warming

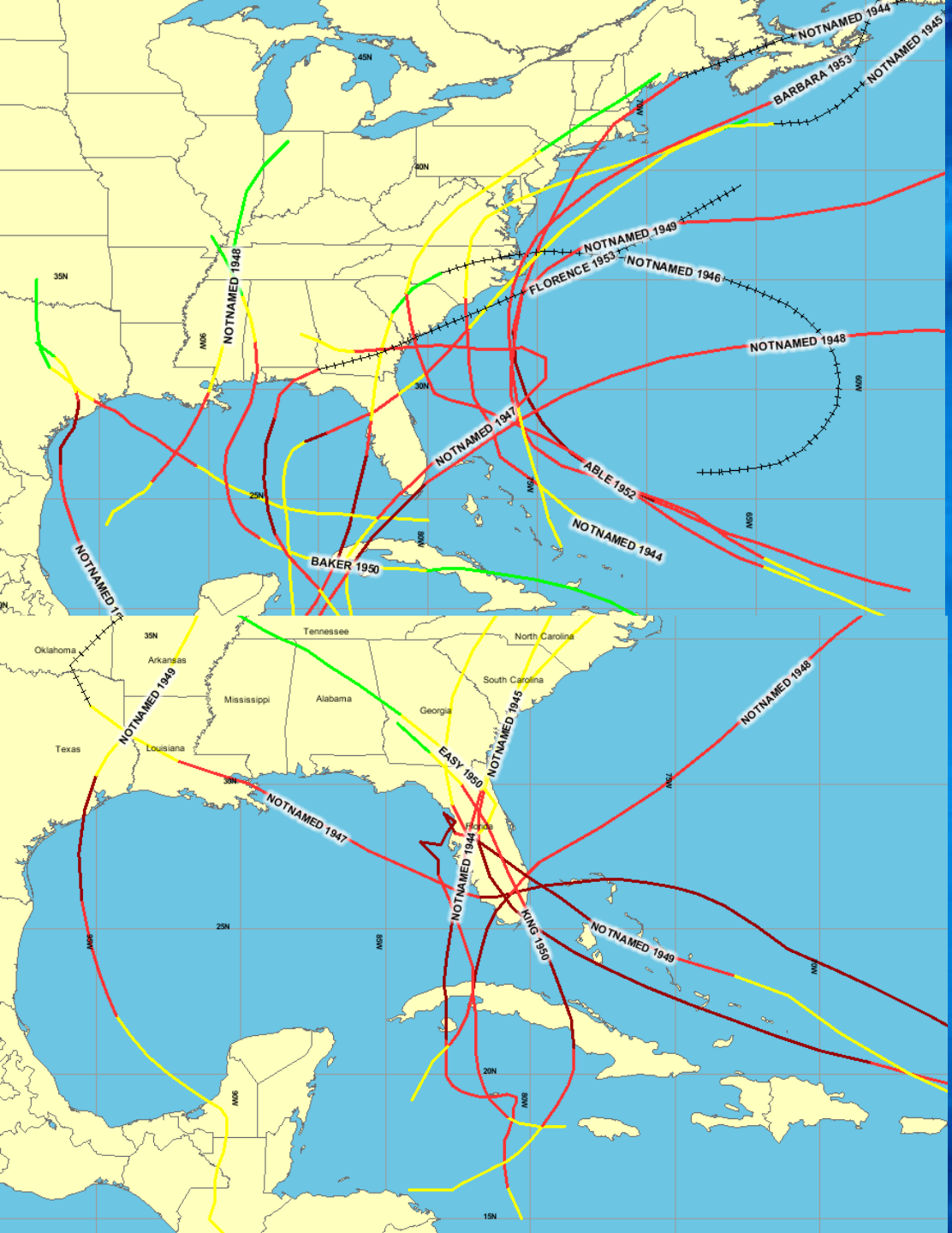
http://www.aoml.noaa.gov/hrd/Landsea/gw_hurricanes/index.html

Tropical storms and hurricanes



Major hurricanes





US Cat 1&2 Hurricanes (1944-1953)

1944-1953:

6 up 1 Category

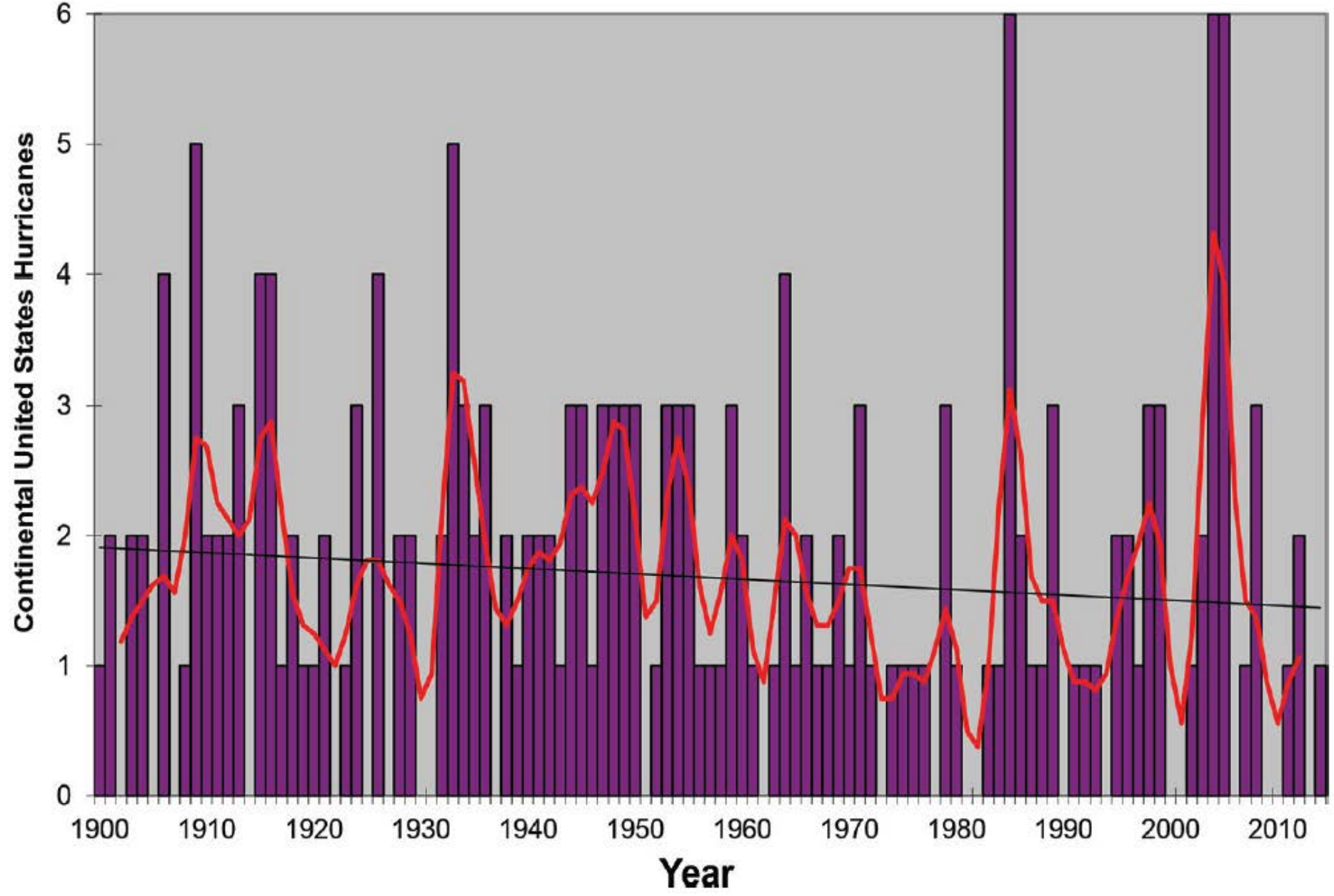
2 down 1 Category

15 unchanged

US Major Hurricanes (1944-1953)

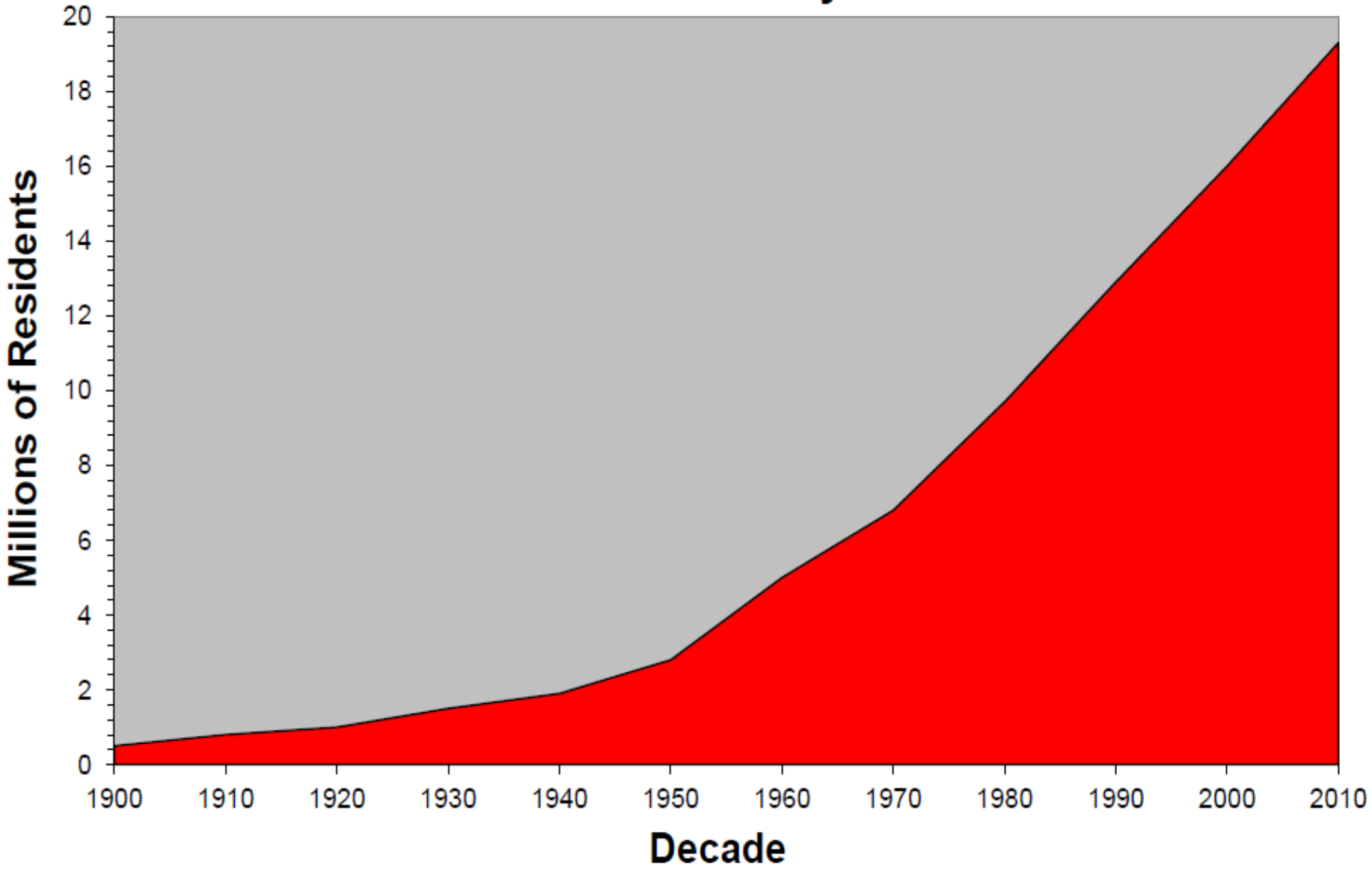
Continental United States Hurricanes

1900 to 2014



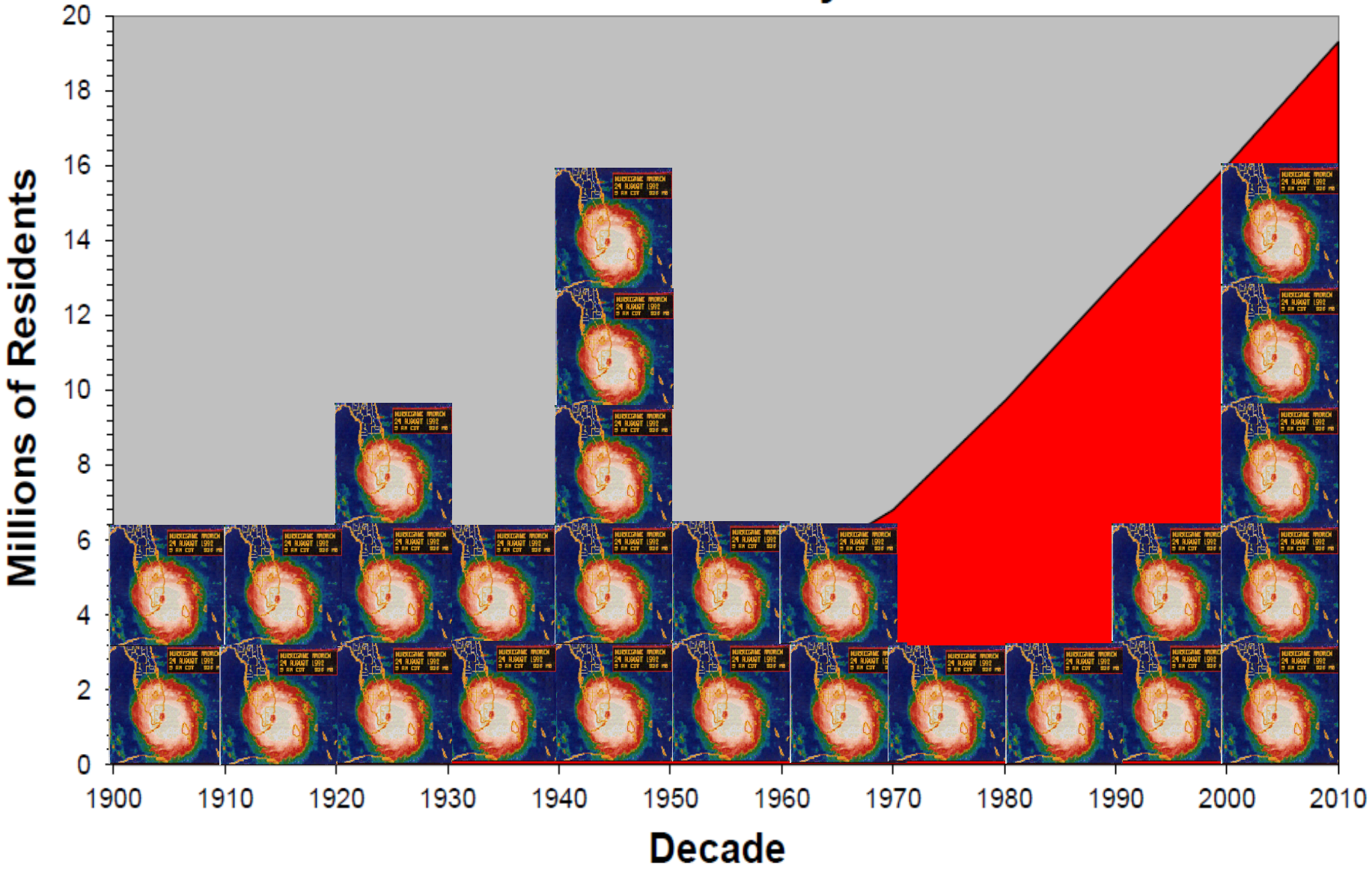
Major Hurricane Strikes and Population for Florida

1900 to today



Major Hurricane Strikes and Population for Florida

1900 to today



Accomplishments:

2000 – Added in 241 new TCs for 1851-1885
2002 – Reanalyzed 1992's Hurricane Andrew
2003 – Reanalyzed 1886-1910 – Revised all 194 TCs, 23 new TCs, removed one TC
2005 – Reanalyzed 1911-1914 – Revised all 15 TCs, 5 new TCs
2008 – Reanalyzed 1915-1920 – Revised all 34 TCs, 8 new TCs, removed one TC
2009 – Reanalyzed 1921-1925 – Revised all 27 TCs, 10 new TCs, removed one TC
2010 – Reanalyzed 1926-1930 – All 29 TCs revised, 4 new TCs
2012 – Reanalyzed 1931-1935 – All 58 TCs revised, 15 new TCs, 4 removed TCs
2012 – Reanalyzed 1936-1940 – All 46 TCs revised, 7 new TCs, 1 removed TC
2013 – Reanalyzed 1941-1945 – All 48 TCs revised, 4 new TCs
2014 – Reanalyzed 1946-1950 – All 50 TCs revised, 9 new TCs
2014 – Reanalyzed 1969's Hurricane Camille
2015 – Reanalyzed 1951-1955 – All 54 TCs revised, 12 new TCs

Overall: Revised 555 existing tropical cyclones
Added 339 new tropical cyclones
Removed 9 tropical cyclones

Highlights for the Atlantic hurricane reanalysis project - 1944 to 1953:

a) Primarily **minor track** alterations were implemented for existing TCs

b) Primarily **major intensity** changes were incorporated into existing TCs, either toward stronger or weaker winds

c) 18 new TCs were discovered and added into HURDAT (none were removed)

d) 10 major continental U.S. hurricanes were identified (1 more than previously) – **5** went **up** a Category, **2** went **down** a Category, and **3** had no change in Category

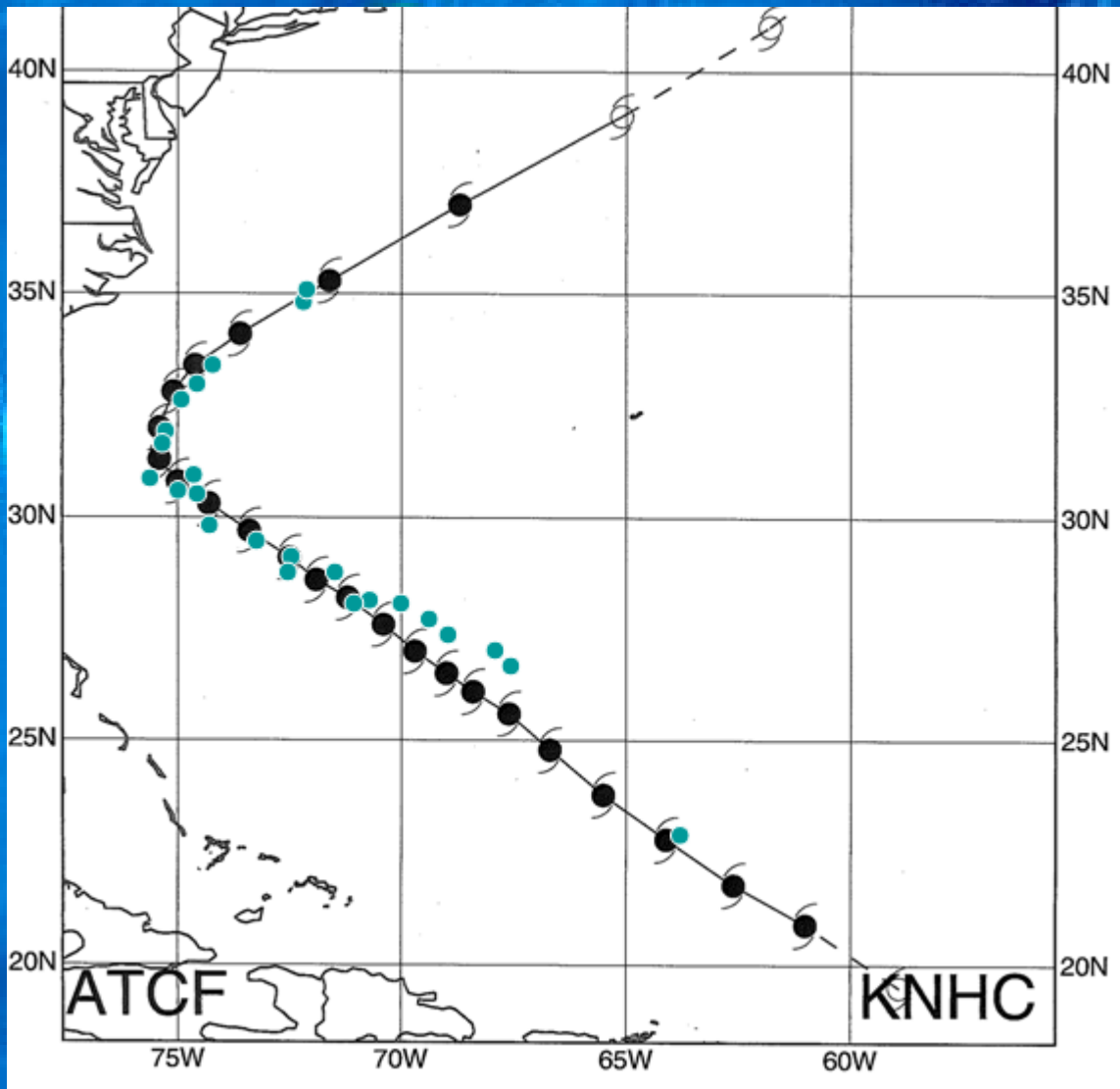
e) There still exists significant uncertainty in TC tracks, significant undercounts in TC frequency, and significant underestimation of TC intensity and duration

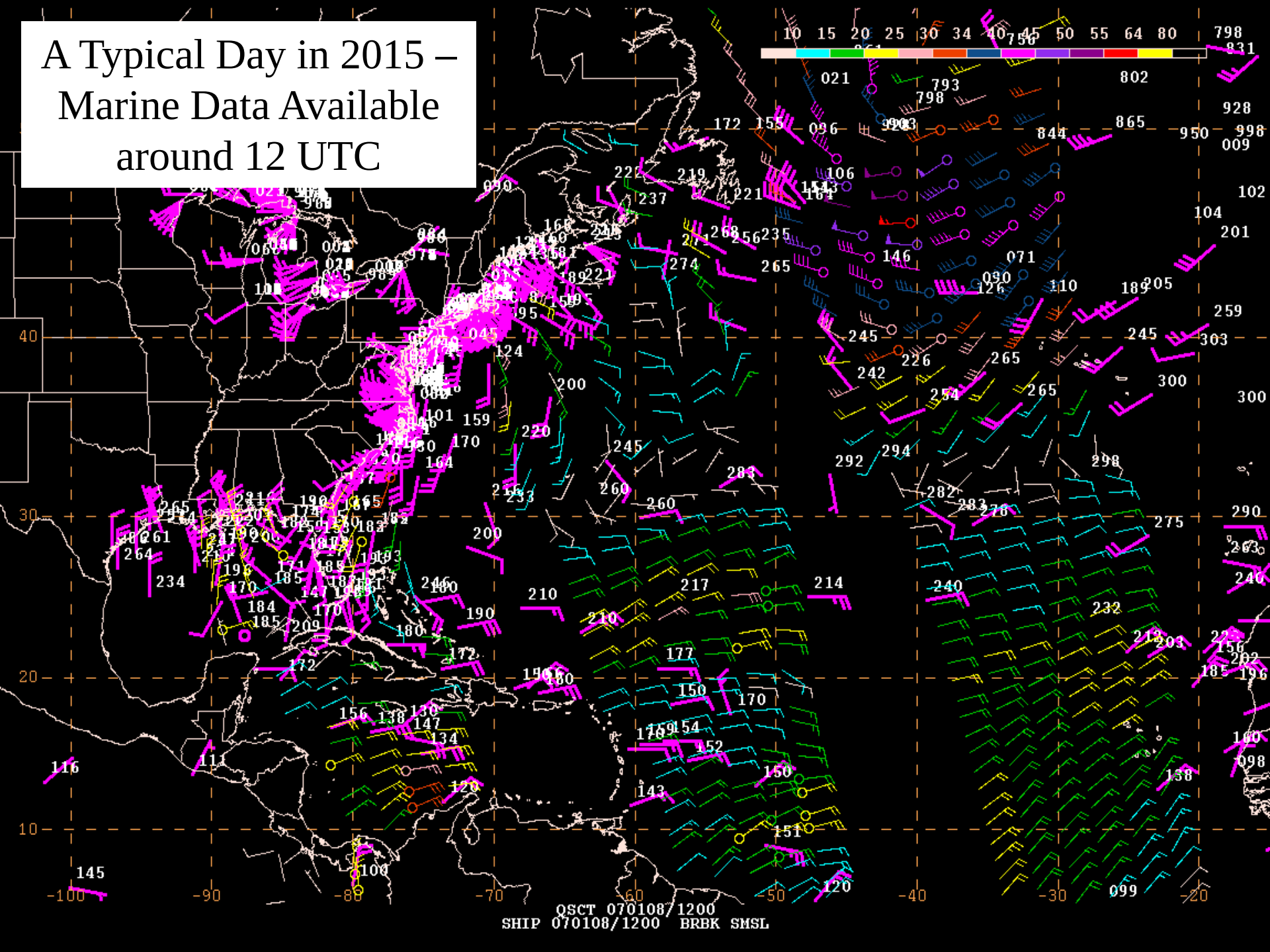
Camille U.S. Landfall

- Landfall – 0400Z 18 August – 30.3N 89.4W, Waveland, MS
- 900 mb central pressure, 10 nm RMW, 15 kt forward speed, 1004 mb outer closed isobar, 150 nm radius OCI
- Brown et al. pressure-wind relationship:
  - 148 kt north of 25N, 155 kt north of 25N intensifying
- **150 kt maximum 1-min, 10 m wind at landfall**
- Run of Kaplan-DeMaria inland wind decay four hours after landfall gives 101 kt, very close to 104 kt fastest mile wind measured at Columbia, MS

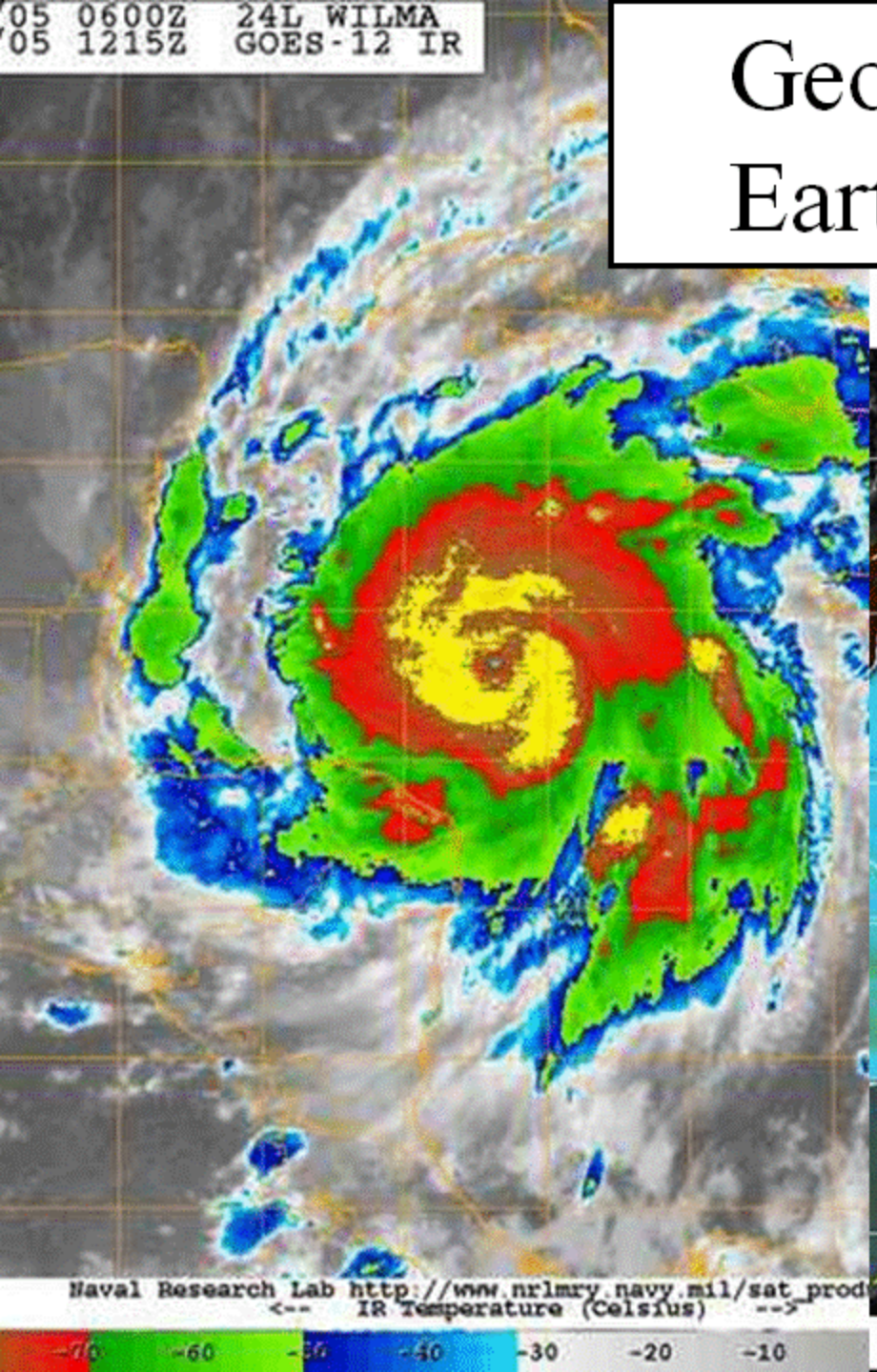
Track analysis methodology (with abundant recon fixes)

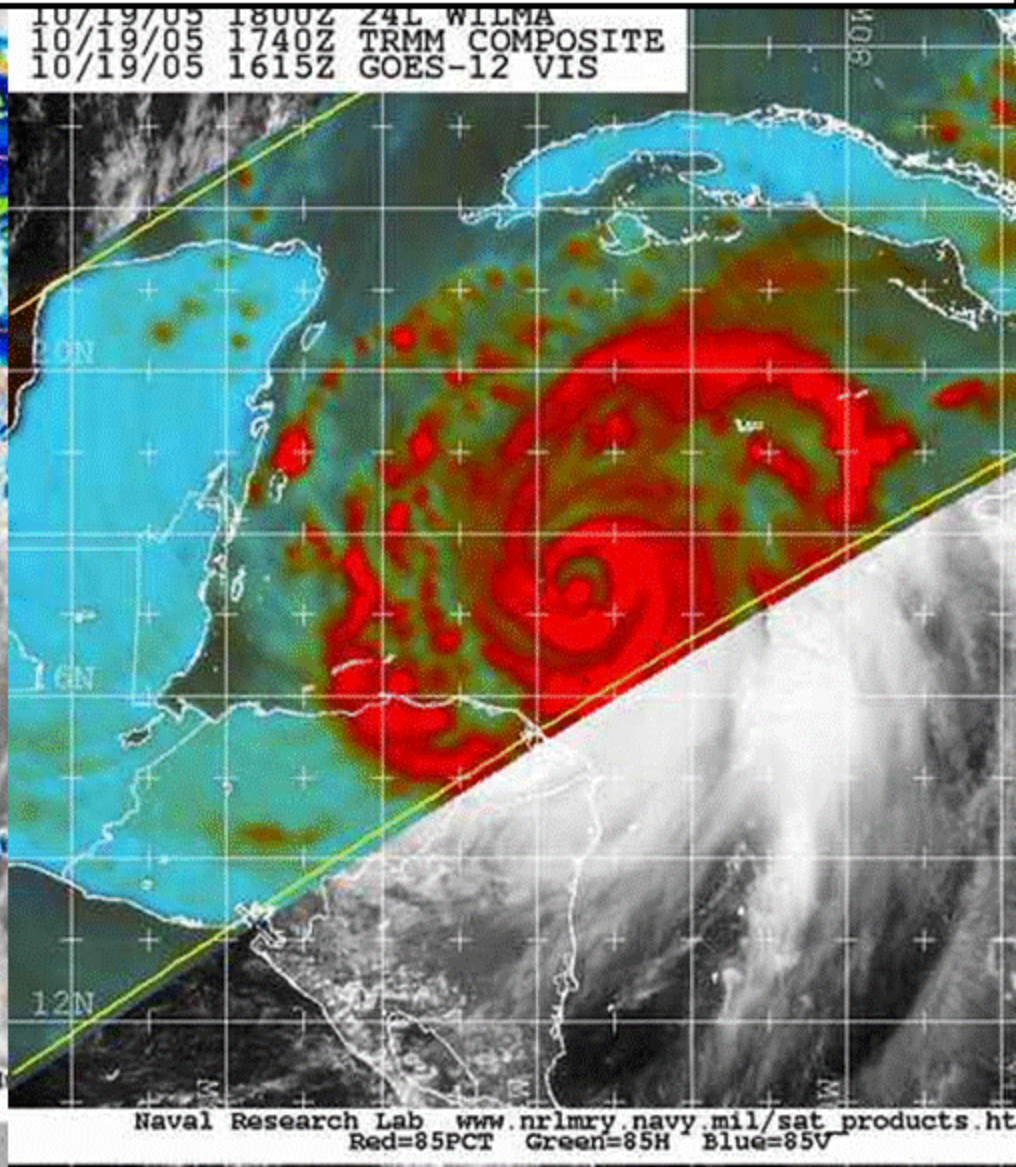
- All center fixes compiled
- Fixes plotted and interpolated to 6-hourly positions
- Ship and station data plotted against aircraft data
- Final revised positions are a consensus of all data
- If there is a lack of data, significant changes are not implemented




A Typical Day in 2015 – Marine Data Available around 12 UTC
10 15 20 25 30 34 40 45 50 55 64 80
QSCT 070108/1200
SHIP 070108/1200 BRBK SMSL

Geostationary and Low-Earth Orbiting Satellites

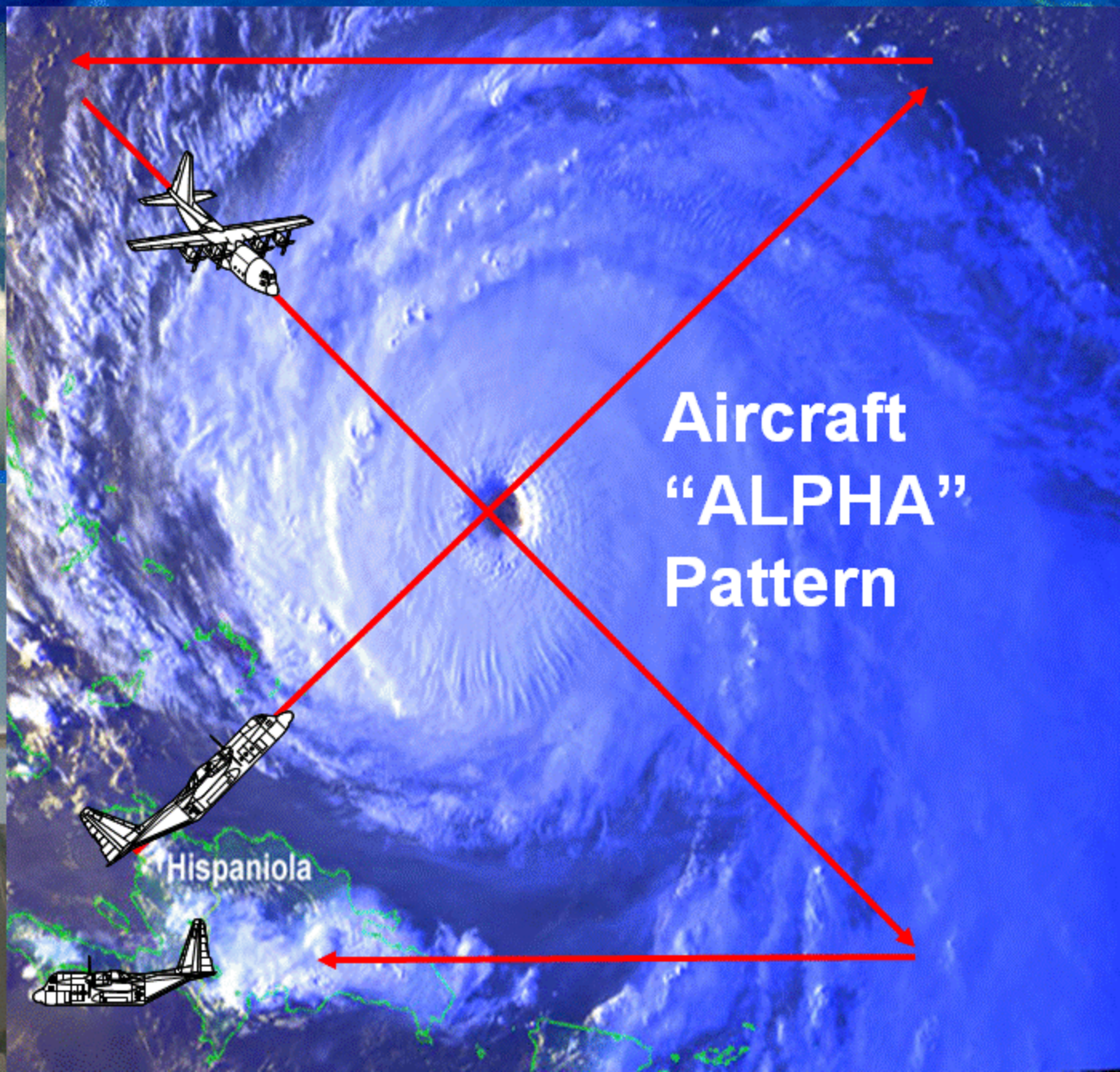




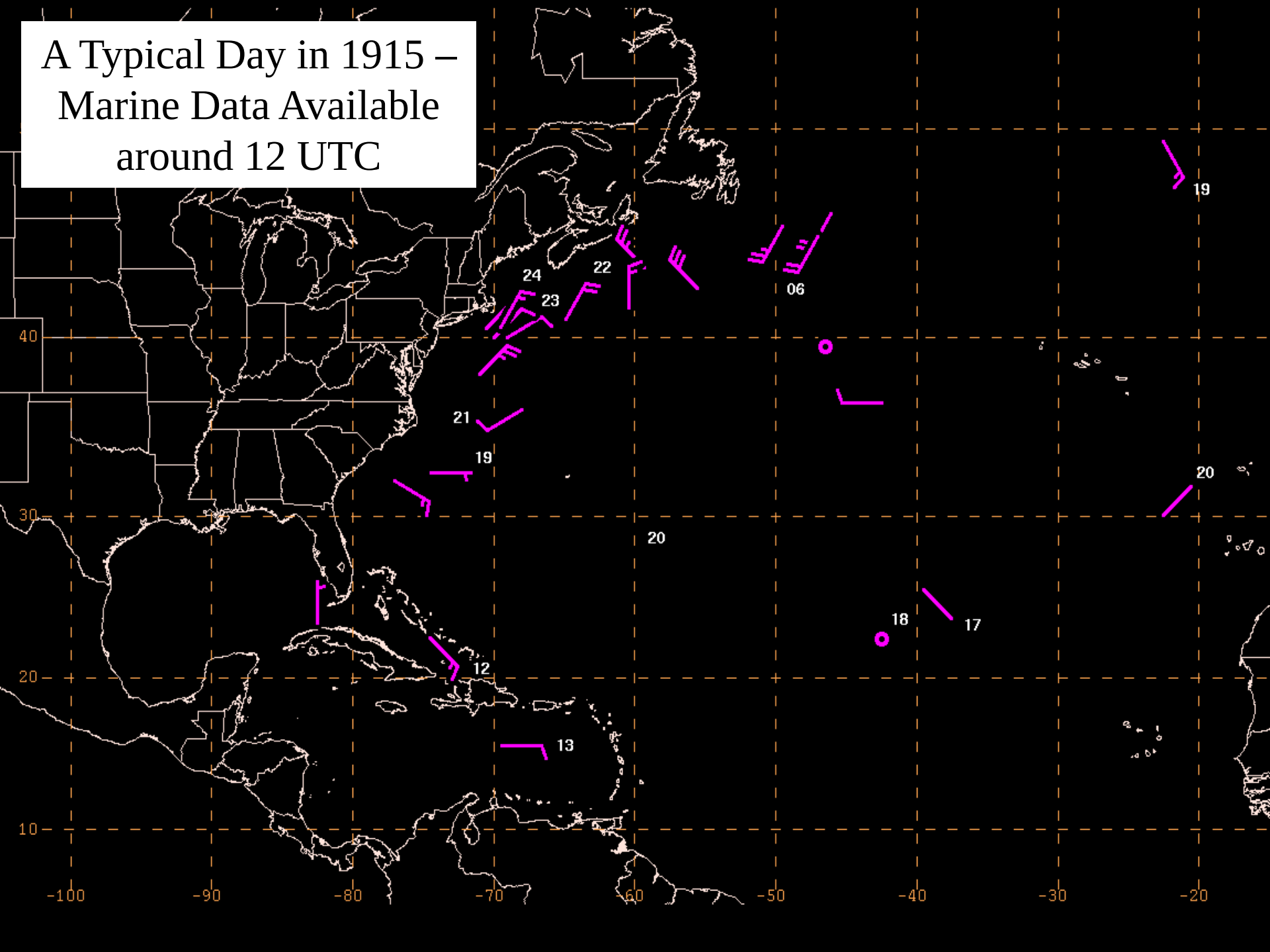
RECONNAISSANCE FLIGHT PATH

NOAA
Orion-P3s

Air Force
C-130s



Aircraft
"ALPHA"
Pattern


A Typical Day in 1915 – Marine Data Available around 12 UTC
19
24
22
23
06
40
21
19
20
30
20
18
17
12
13
10
-100
-90
-80
-70
-60
-50
-40
-30
-20

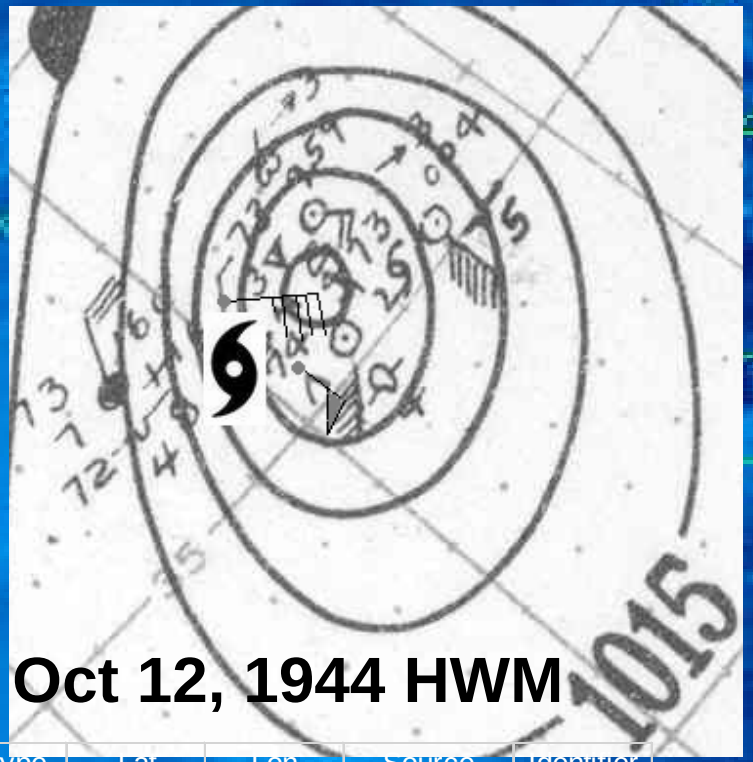
A Typical Day in 1911
M

Aircraft Reconnaissance Missions into Camille

1944 missing hurricane found

New to HURDAT:

On the 12th, there are seven observations of gale force winds, two of them being hurricane force winds. Low pressures (down to 998 mb) are observed with these high winds, and these observations are all in close proximity of the cyclones center. Peak intensity of a 70 kt hurricane is analyzed from 12Z on the 12th to 00Z on the 13th.

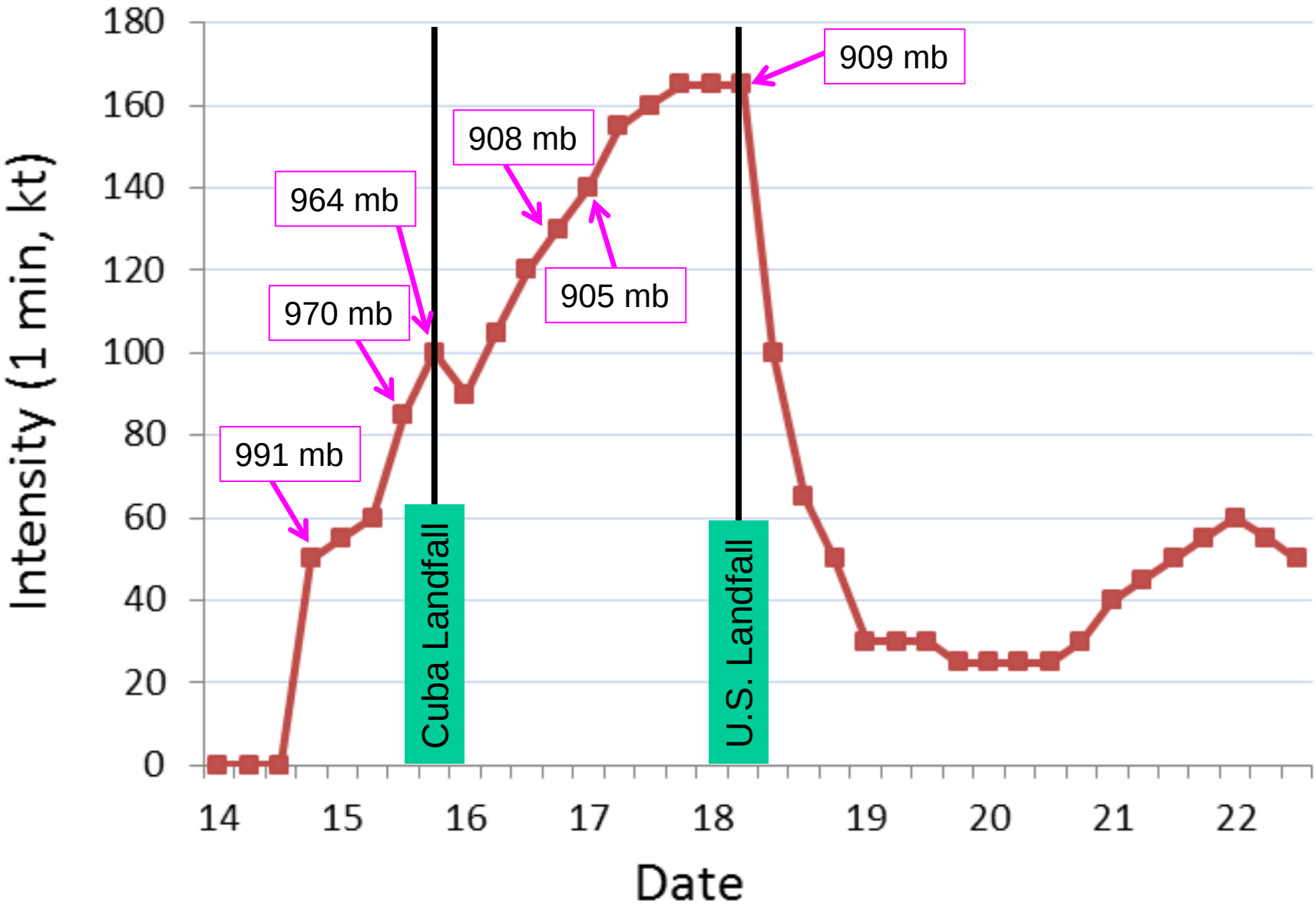


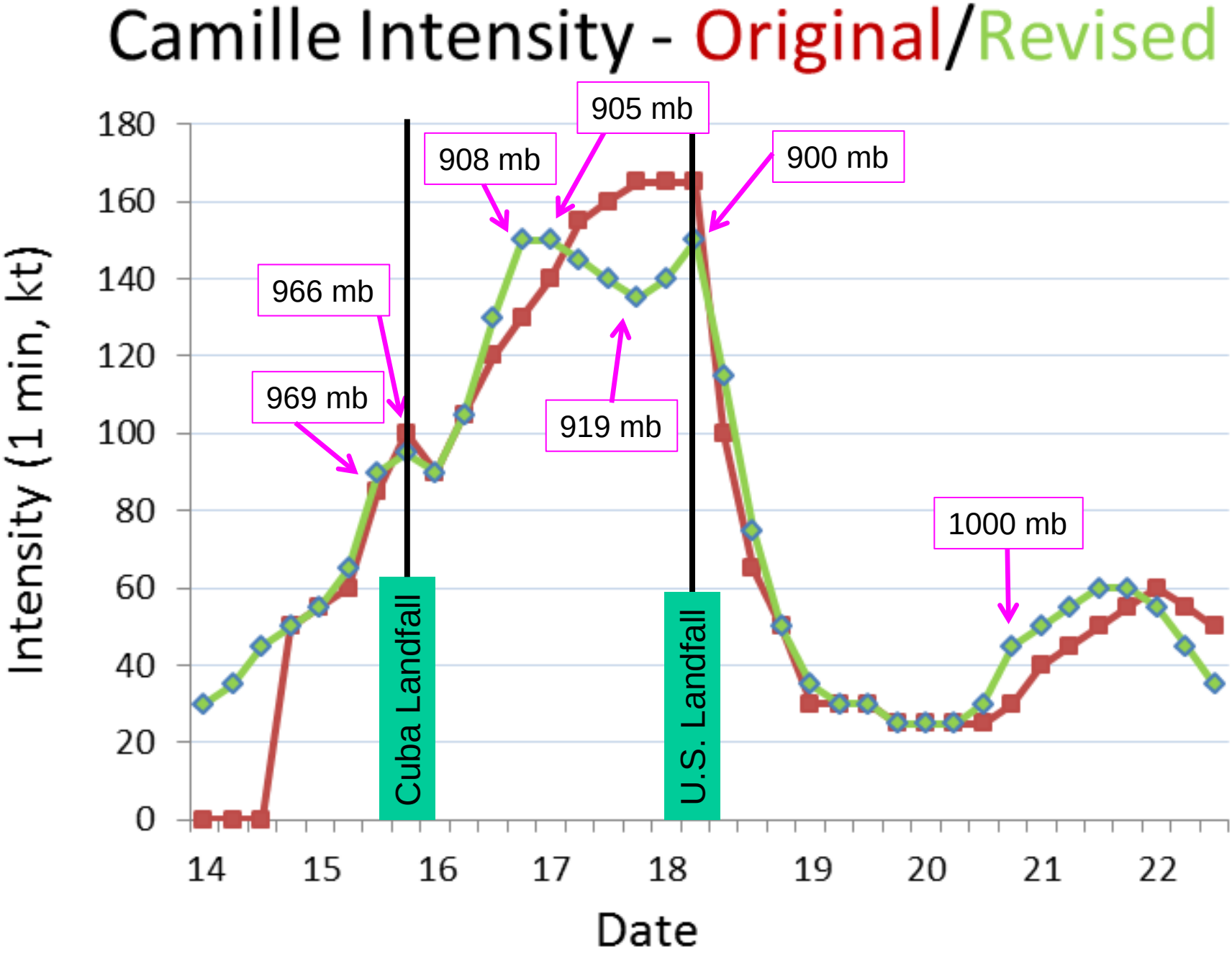
Oct 12, 1944 HWM

Key observations:

Date	Time	Pressure	Wind (kt)	Dir	Air Temp	SST	Ob type	Lat	Lon	Source	Identifier
11-Oct	15Z	**1005**	25	NE	75		SHIP	375	415	COA	37016
11-Oct	19Z	1011	**40**	NNE	74		SHIP	365	405	COA	
11-Oct	23Z		**45**	N	76	74	SHIP	365	415	COA	61132
11-Oct	23Z	1012	**35**	NE	74	75	SHIP	365	405	COA	14352
11-Oct	23Z	1011	**35**	NNE	75	76	SHIP	365	405	COA	61061
12-Oct	10Z	**1000**	**65**	S	73	73	SHIP	355	375	COA, HWM	14352
12-Oct	11Z		**50**	S	74	72	SHIP	355	395	COA	61132
12-Oct	11Z	**998**	**45**	SE	72		SHIP	365	395	COA	
12-Oct	11Z	**996**	10	SE	73	74	SHIP	365	385	COA, HWM	61061
12-Oct	12Z		**50**	SW	74		SHIP	352	389	HWM	
12-Oct	14Z	1010	**70**	S	74	74	SHIP	355	375	COA	14352
12-Oct	14Z	1006	**45**	S	75	74	SHIP	355	375	COA	61061
12-Oct	15Z		**60**	S	73	74	SHIP	355	395	COA	61132
12-Oct	15Z	1008	**45**	S	73		SHIP	365	385	COA	

Camille Intensity - Original




Camille Intensity - Original/Revised
905 mb
908 mb
900 mb
966 mb
969 mb
919 mb
1000 mb
Cuba Landfall
U.S. Landfall
Intensity (1 min, kt)
180
160
140
120
100
80
60
40
20
0
14
15
16
17
18
19
20
21
22
Date

Work of Jose Partagas: Historical Reconstruction from 1851-1910

Researcher's ashes tossed in storm's eye

By CURTIS MORGAM
Herald Staff Writer

As the P-3 Orion research plane bumped and rolled through one last circle inside Hurricane Danielle, Peter Black placed a simple cloth sack into a chute and sent its contents swirling into the atmosphere.

And at 10:05 p.m. Sunday, latitude 28.0 north, longitude 74.2 west, 400 miles east-northeast of Miami, Jose Fernandez Partagas finally got a send-off fellow weather scientists know he would have appreciated: His ashes were scattered into the howling heart of an Atlantic hurricane.

"I found it quite a moving experience," Black, a National Oceanographic and Atmospheric Administration research meteorologist, said Tuesday. "It just seemed very appropriate to do it in the eye of a hurricane."

The ceremony, a rare honor, was a gesture of respect for an eccentric but affable researcher who lived to study hurricanes and died, nearly destitute, doing just that. It also rescued Partagas from an obscure burial. After his death a year ago in August at age 62, police found no relatives. His father had died in Cuba, his mother in Miami and he had never married.

When no one claimed the body, the National Hurricane Center did.

"They didn't want Jose to go to a pauper's grave," said Jim Gross, a center research meteorologist. Gross stored the ashes, awaiting a scheduled storm flight with the right conditions for the brief ceremony, attended by six scientists and most of the 11 crew members.

"We think Jose would have been honored, happy to have it done this way," Gross said.

Partagas was born and schooled in Cuba, receiving a degree in meteorology from Havana University and working at the national observatory, said friend Luciano Blanco, a retired physicist in Miami who went to school

PLEASE SEE PARTAGAS, 4B

A EULOGY ALOFT

Peter Black, lead National Oceanographic Administration scientist aboard the P-3 Orion research plane, recorded this in the plane's official log for 10:05 p.m., Aug. 30, 1998:

"The crew and the scientists of NOAA aircraft 43RF gathered for a brief ceremony in which the ashes of Jose Fernandez Partagas were scattered into the eye of Hurricane Danielle at latitude 28.0 north, 74.2 west, thus returning Jose to the hurricanes he loved and which formed his life's work."

Partagas