

"This **broad consistency** between observations, models, and theory is a powerful indicator that we are likely already experiencing more intense tropical cyclones as a result of global warming."

--- Anthes, Correll, Holland, Hurrell, MacCracken, Trenberth
--- Bulletin of the American Meteorological Society, 2006

"There is **an inconsistency** between the small changes in wind-speed projected by theory and modeling versus large changes reported by some observational studies."

--- Statement on Tropical Cyclones and Climate Change
--- International Workshop on Tropical Cyclones, 2006

2005

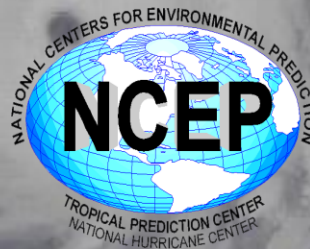
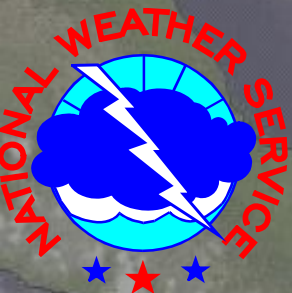
Long-term Hurricane Trends: What's Going on with these Storms?

13 May, 2008

Florida Governor's Hurricane Conference

Chris Landsea

National Hurricane Center, Miami

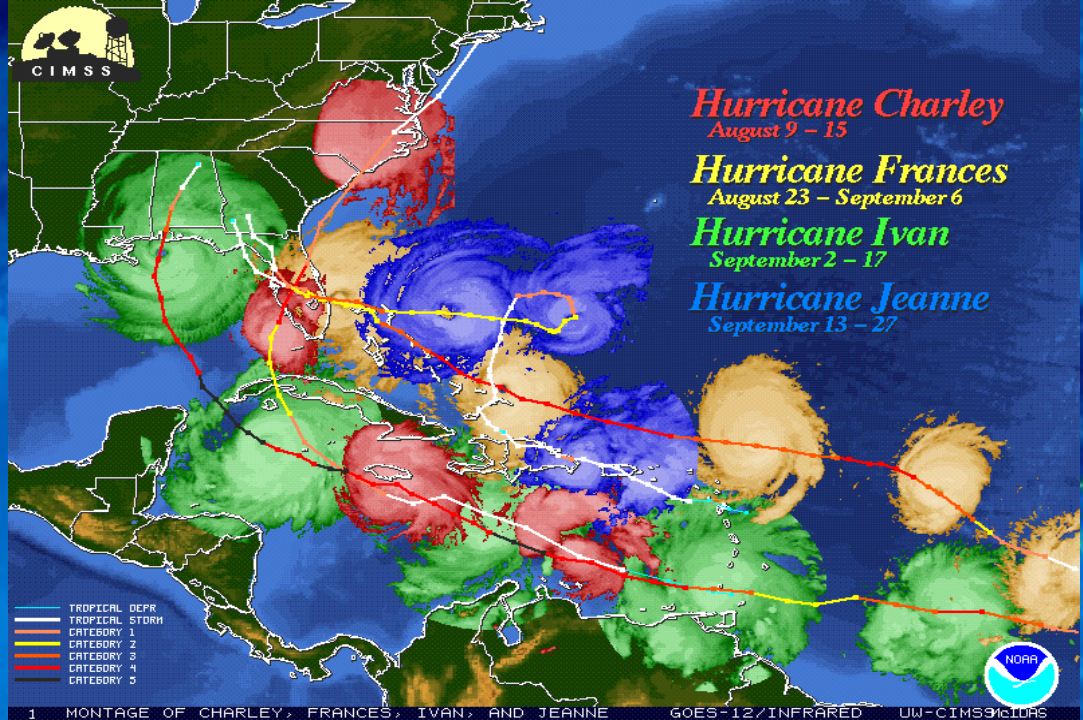


Rita
23 September

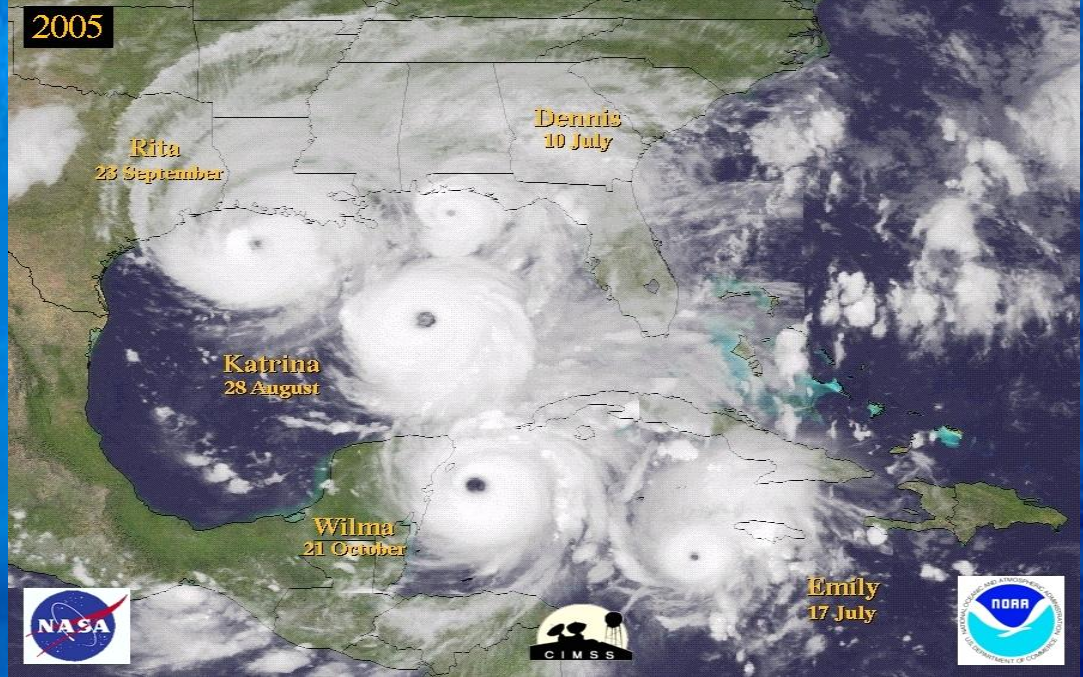
10 July

Katrina
28 August

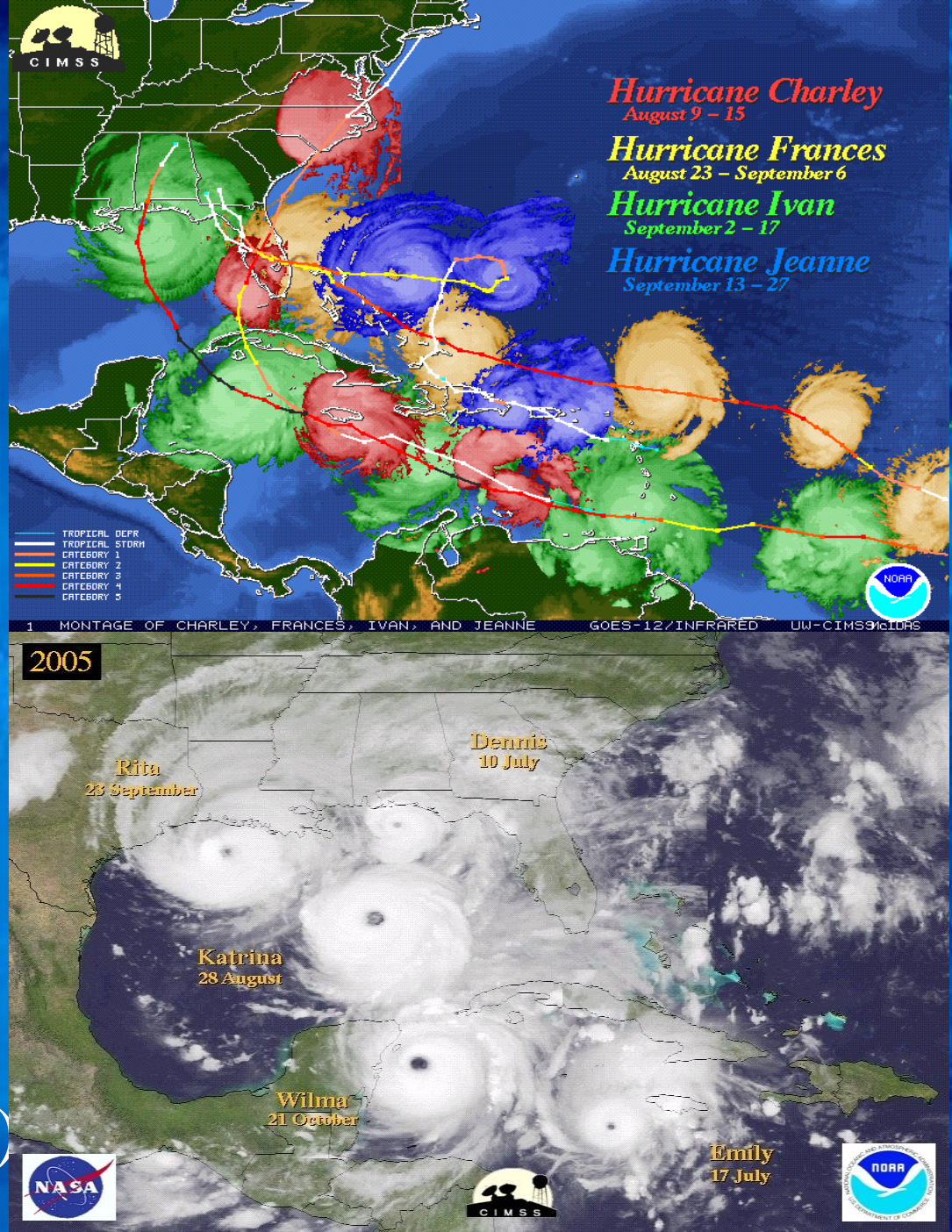
Wilma
21 October

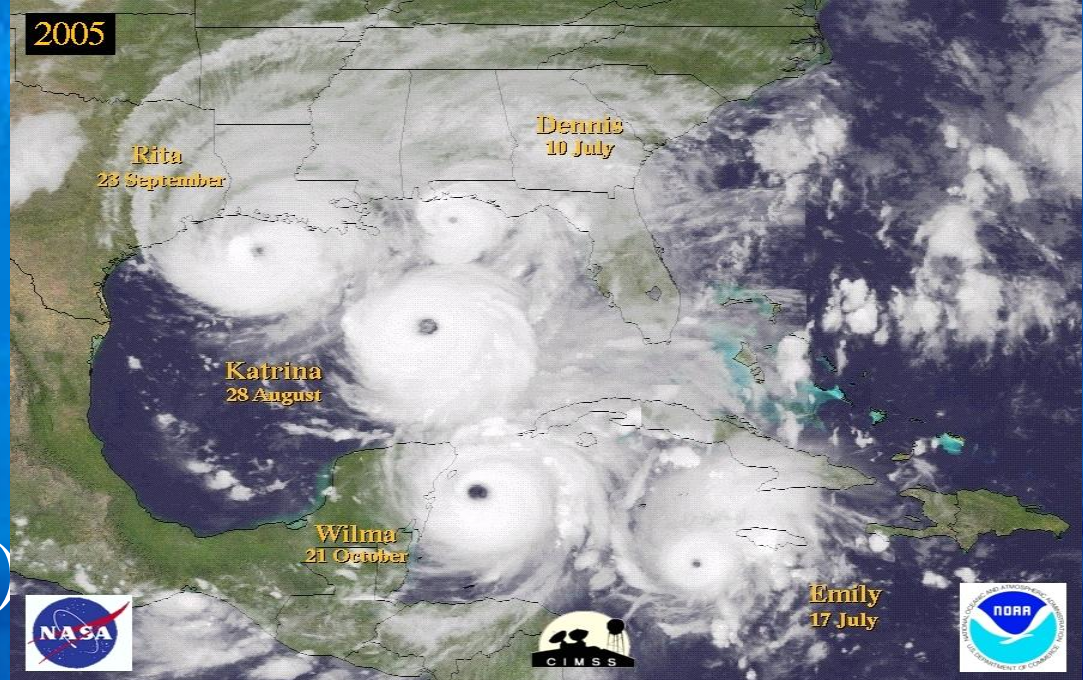
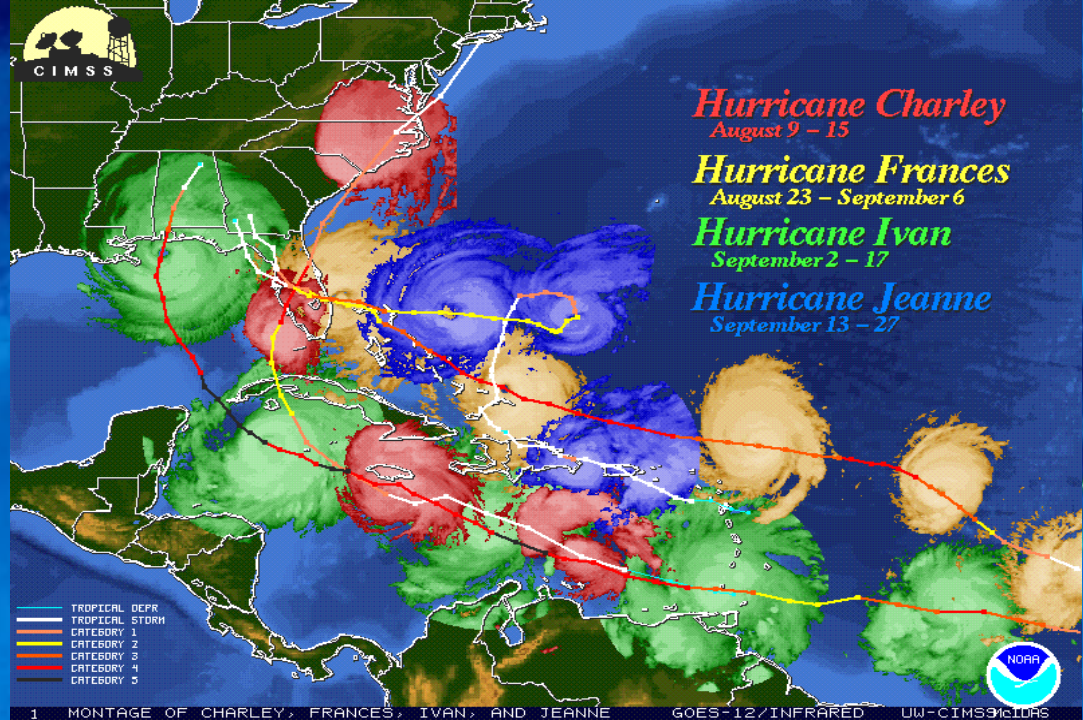


1 MONTAGE OF CHARLEY, FRANCES, IVAN, AND JEANNE GOES-12/INFRARED UW-CIMSS/ILLAS



Emanuel (2005)
Webster et al. (2005)
Mann/Emanuel (2006)





Emanuel (2005)
Webster et al. (2005)
Mann/Emanuel (2006)



Before Katrina...

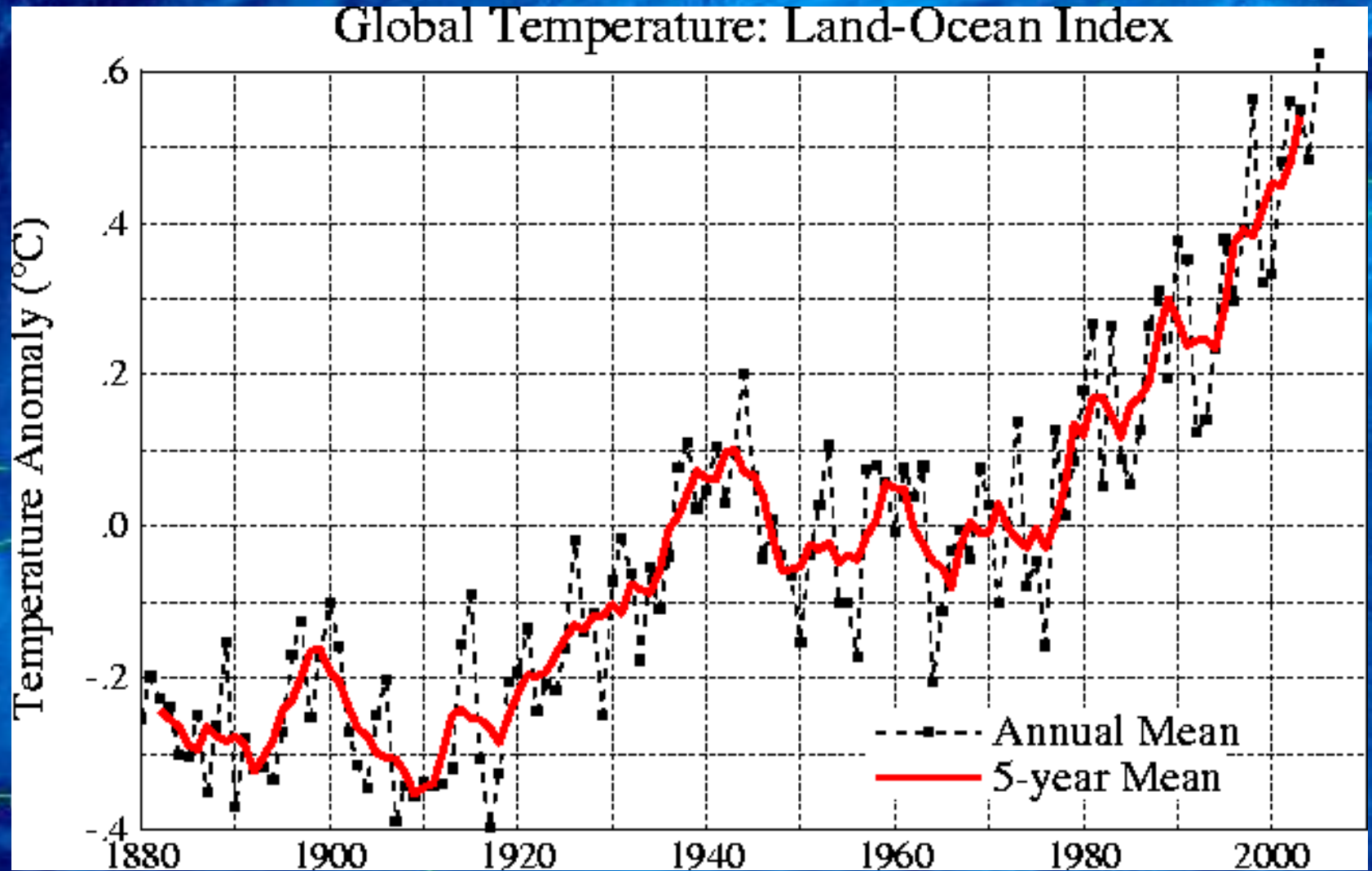
David & Kimberly King
Waveland, MS



...After Katrina

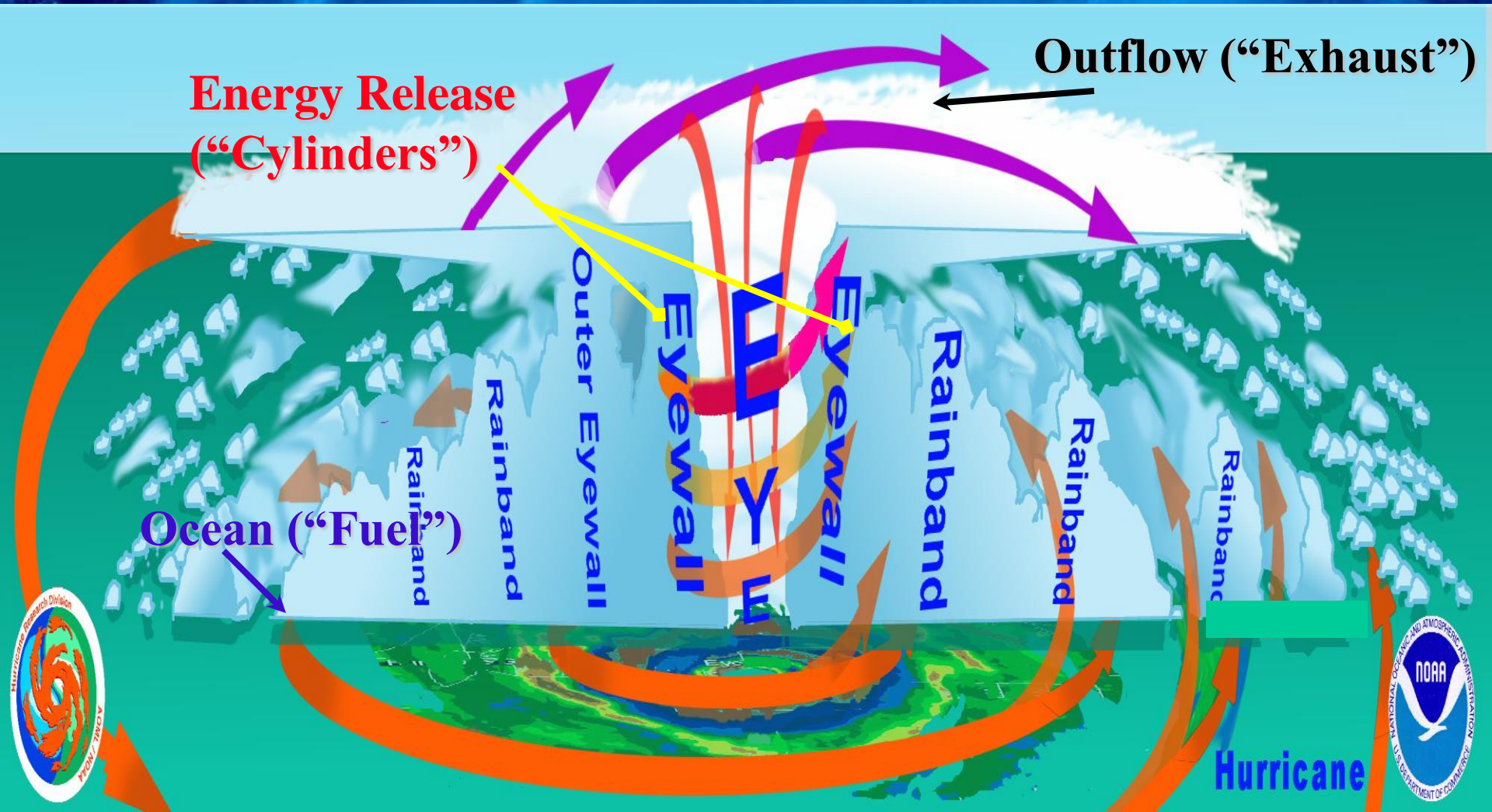
David & Kimberly King
Waveland, MS

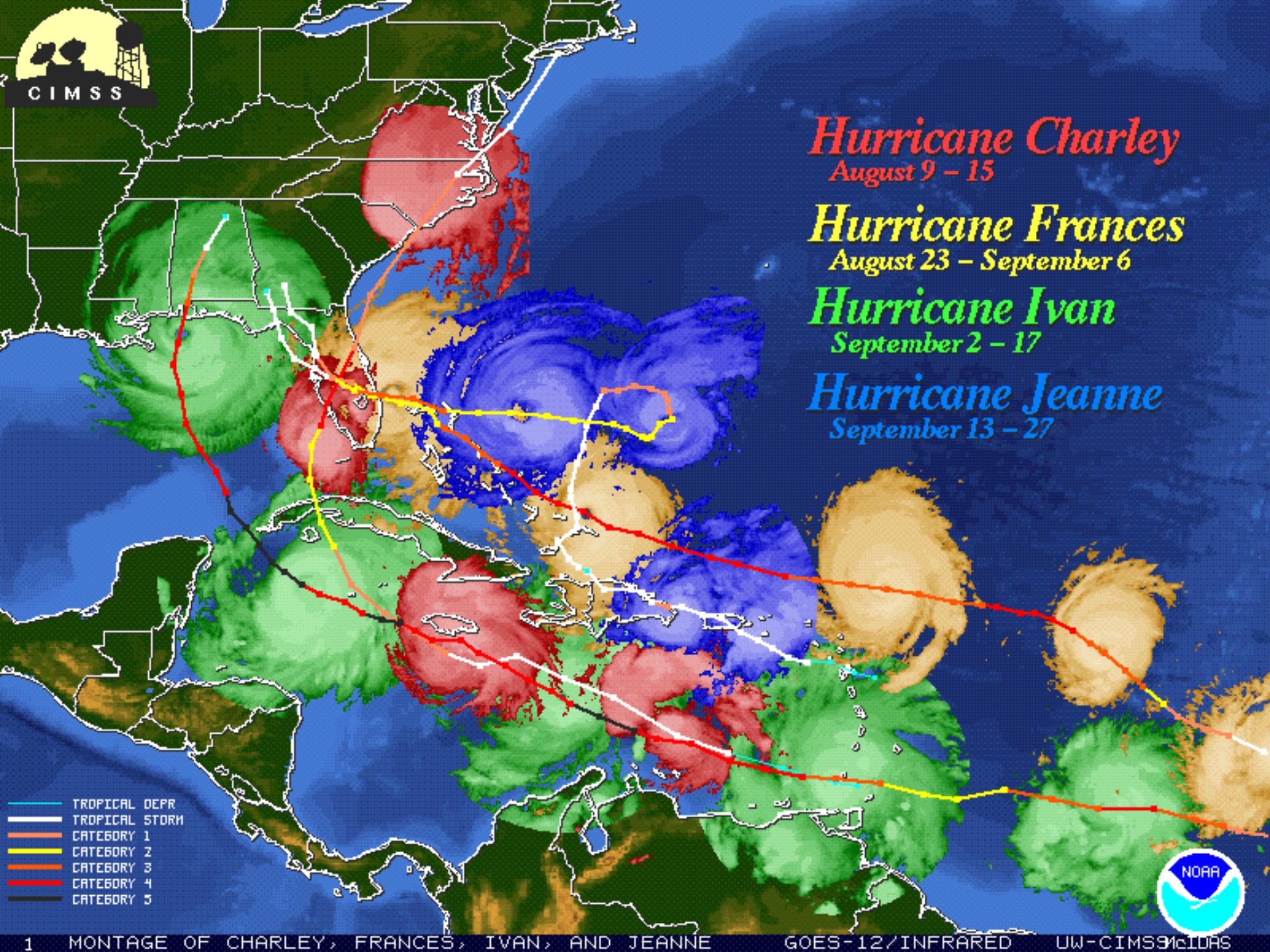
Global Warming – Past Temperature Changes



Nature's great heat engine...

The Hurricane





Hurricane Charley
August 9 - 15

Hurricane Frances
August 23 - September 6

Hurricane Ivan
September 2 - 17

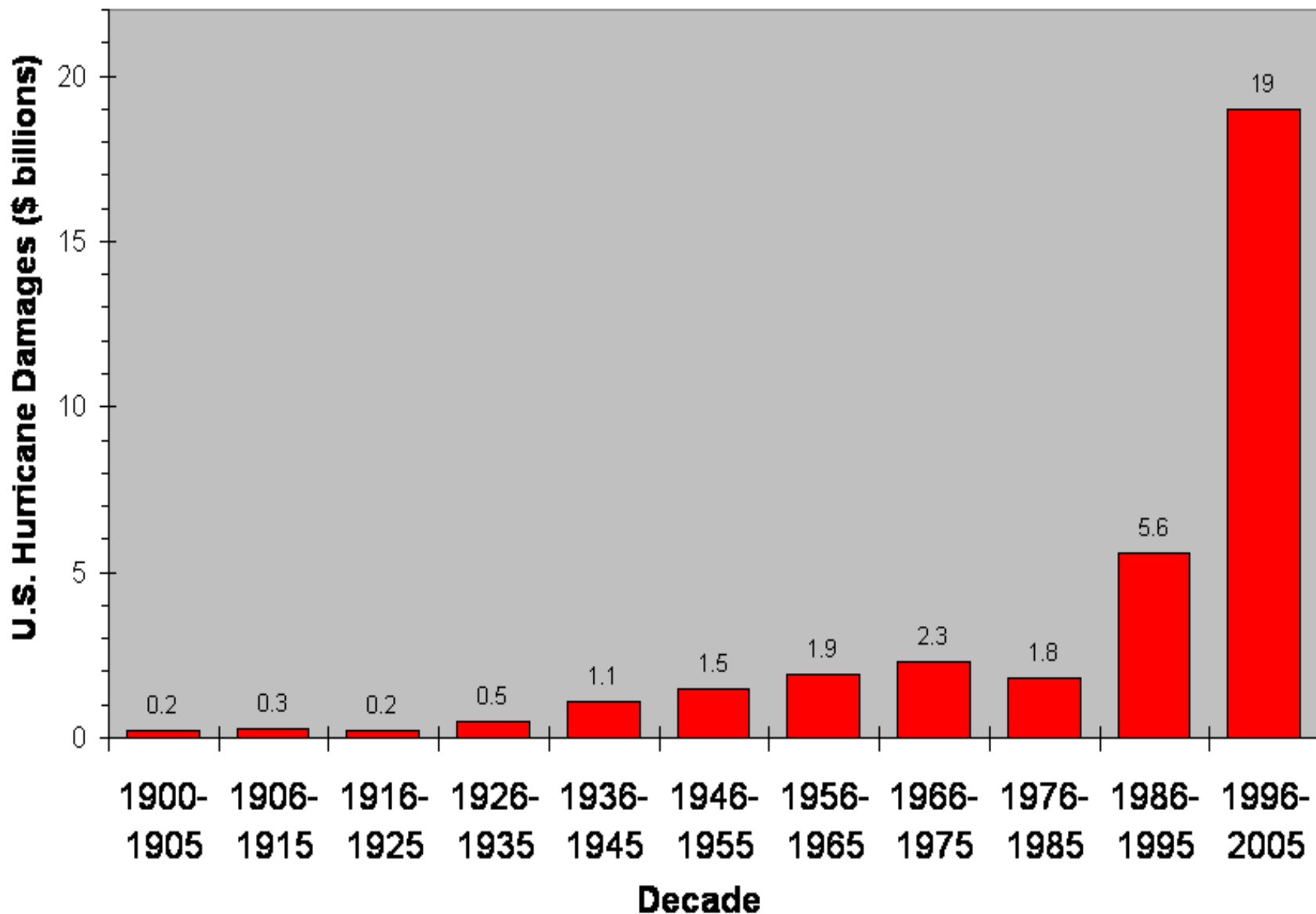
Hurricane Jeanne
September 13 - 27

- TROPICAL DEPR
- TROPICAL STORM
- CATEGORY 1
- CATEGORY 2
- CATEGORY 3
- CATEGORY 4
- CATEGORY 5



U.S. Tropical Storm and Hurricane Damages

\$BILLIONS Annually - Inflation Adjusted



Increases in personal wealth (people have more “stuff”, and larger homes to stow their stuff, etc.) has led to greatly increased damage from hurricanes.



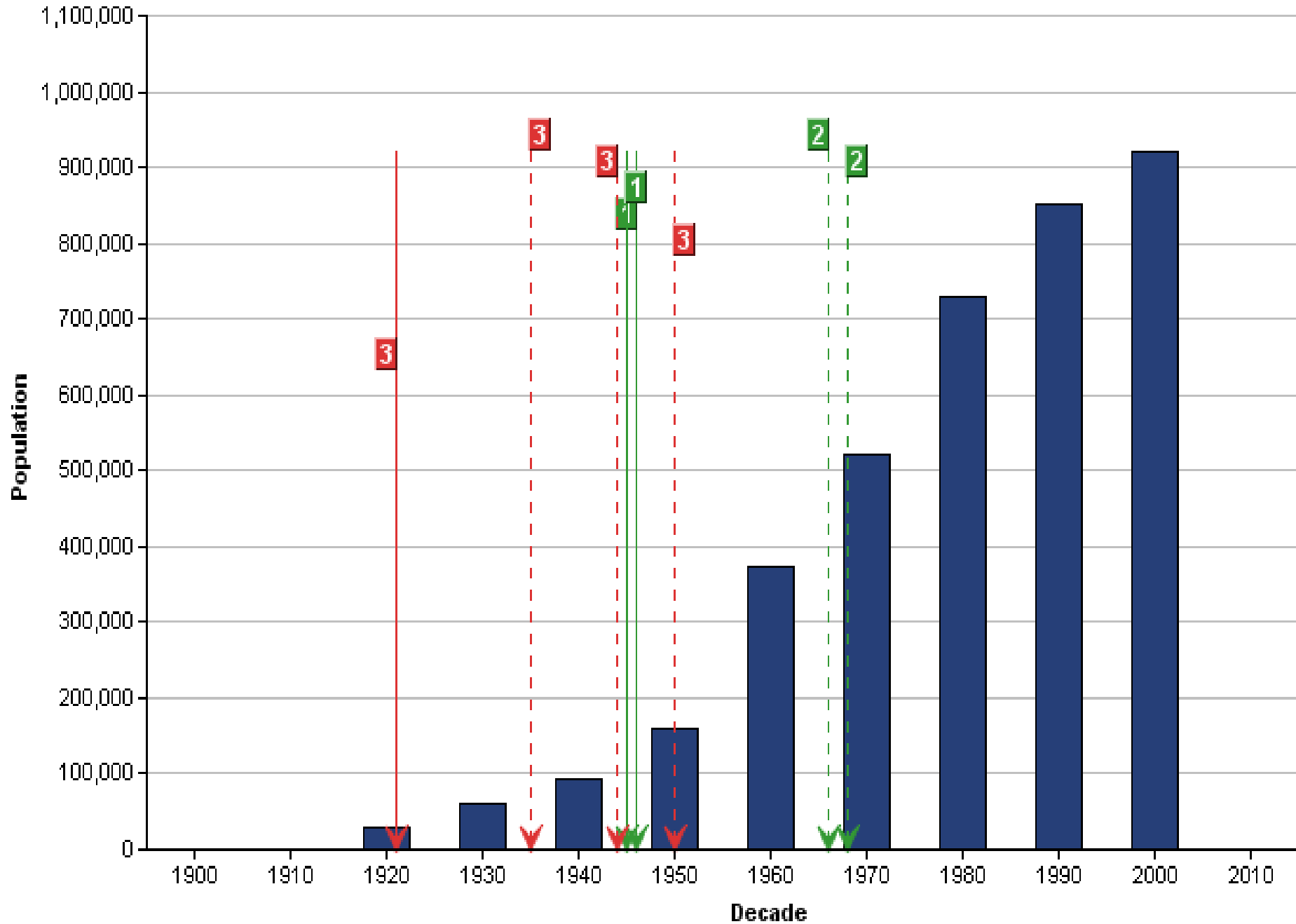


Highway sign with directional arrows.

Highway sign with directional arrows.

Green highway sign with 'EXIT 101' and 'McKINNEY BL'.

Hurricane Strikes vs Population for Pinellas, Florida



NORMALIZED DAMAGE...

Estimated direct damage if past storms made landfall with present-day societal conditions

$ND = f(\text{inflation, coastal population, wealth})$

Pielke and Landsea (1998)

$ND = f(\text{inflation, coastal housing, wealth})$

Pielke et al. (2008)

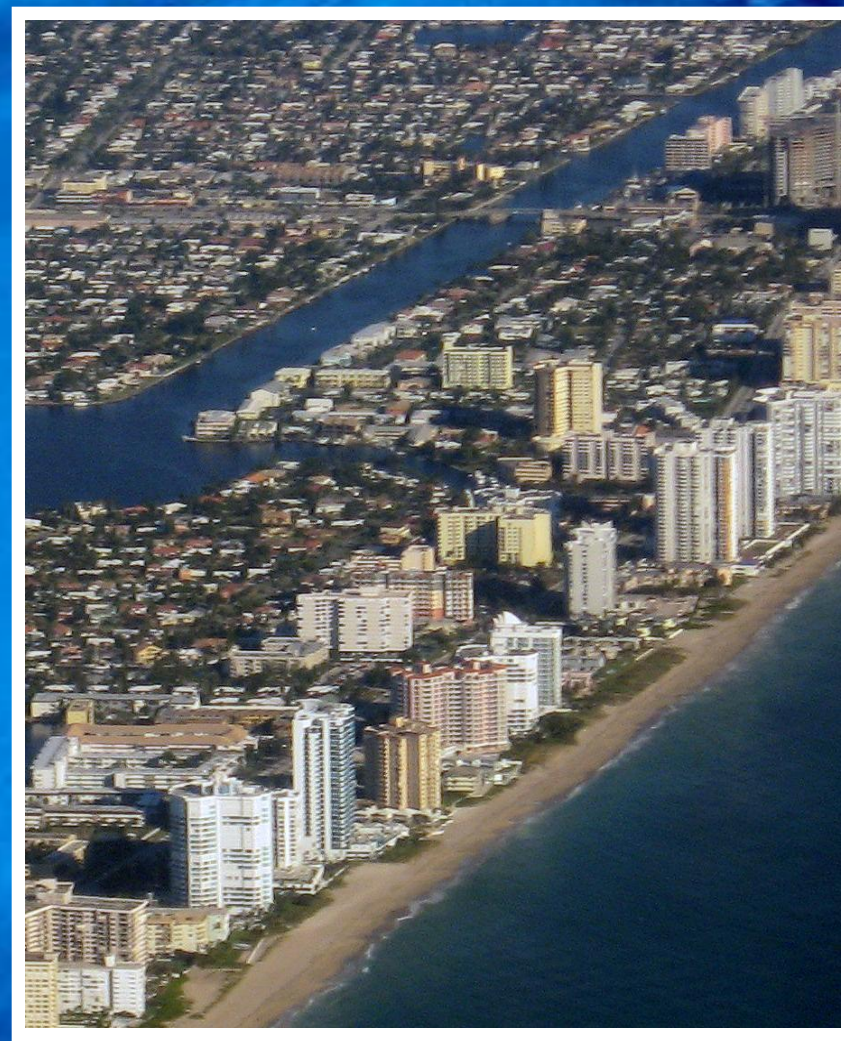
1926 GREAT MIAMI HURRICANE

\$140-157 BILLION TODAY

Miami Beach 1926

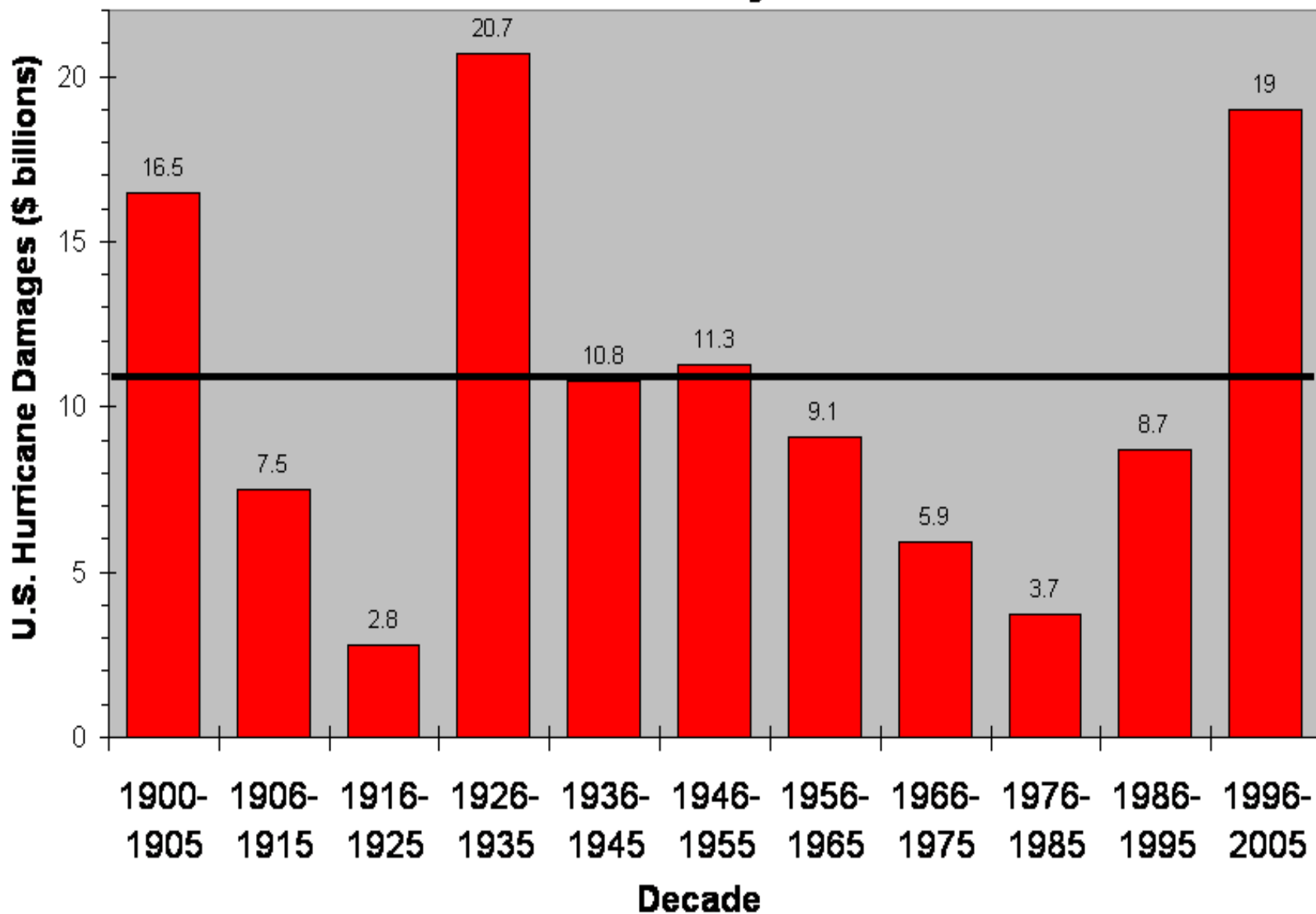


Miami Beach 2006

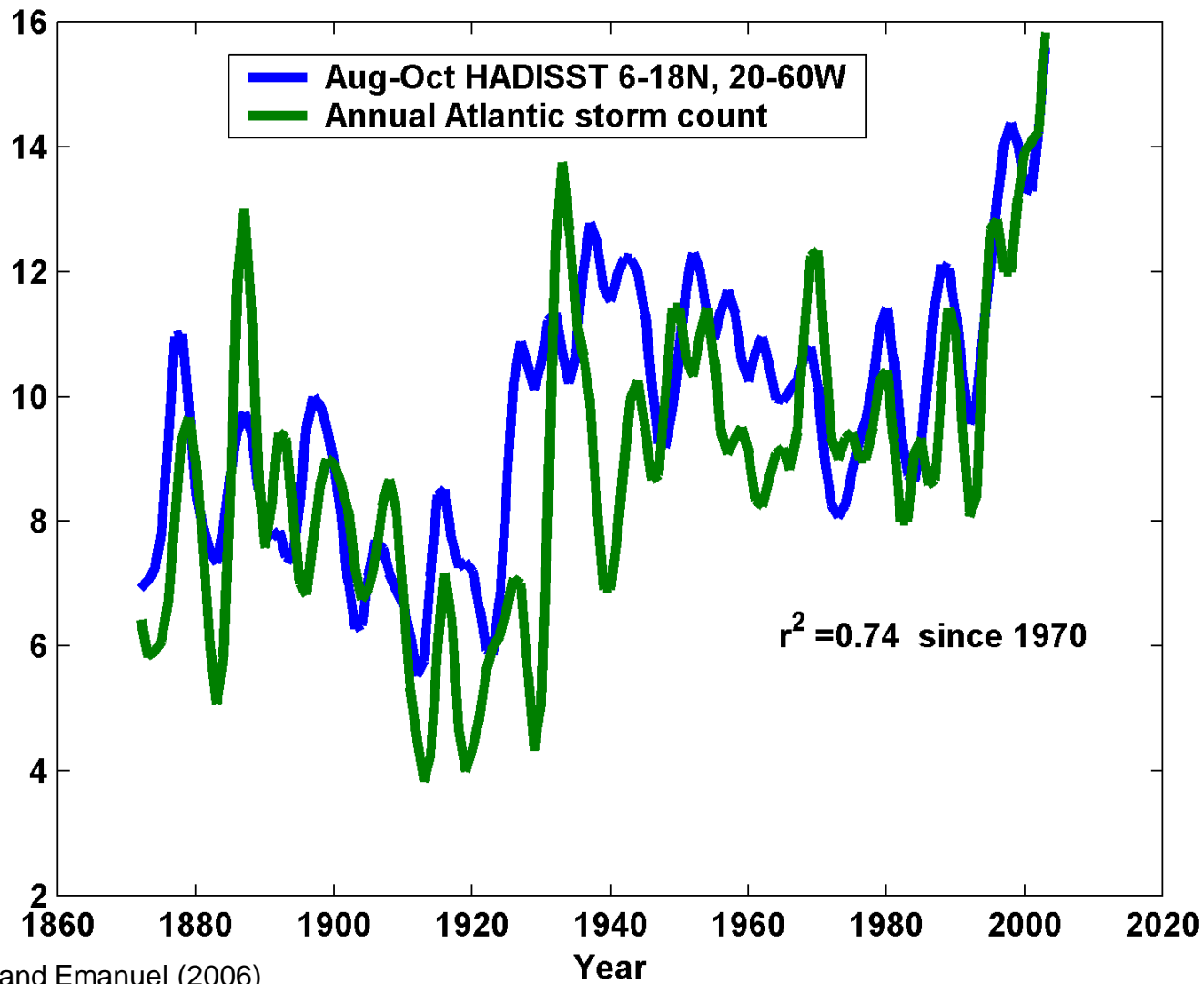


U.S. Tropical Storm and Hurricane Damages

\$BILLIONS Annually - Normalized



Linking frequency of Atlantic tropical cyclones to SSTs



Mann and Emanuel (2006)

2005 Hurricane Season

NUMBER	TYPE	NAME	DATE
1	T	ARLENE	8 Jun.-13 Jun.
2	T	BRET	28 Jun.-30 Jun.
3	H	CINDY	3 Jul.-7 Jul.
4	H	DENNIS	4 Jul.-13 Jul.
5	H	EMILY	11 Jul.-21 Jul.
6	T	FRANKLIN	21 Jul.-29 Jul.
7	T	GERT	23 Jul.-25 Jul.
8	T	HARVEY	2 Aug.-8 Aug.
9	H	IRENE	4 Aug.-18 Aug.
10	T	JOSE	22 Aug.-23 Aug.
11	H	KATRINA	23 Aug.-30 Aug.
12	T	LEE	28 Aug.-2 Sep.
13	H	MARIA	1 Sep.-10 Sep.

- Hurricane (H)
- Tropical Storm (T)
- Tropical Dep.
- Extratropical
- Wave/Low
- Subtropical Depression
- Subtropical Storm (ST)
- Position at 0000 UTC
- Position/date at 1200 UTC
- 5 Tropical Cyclone Number

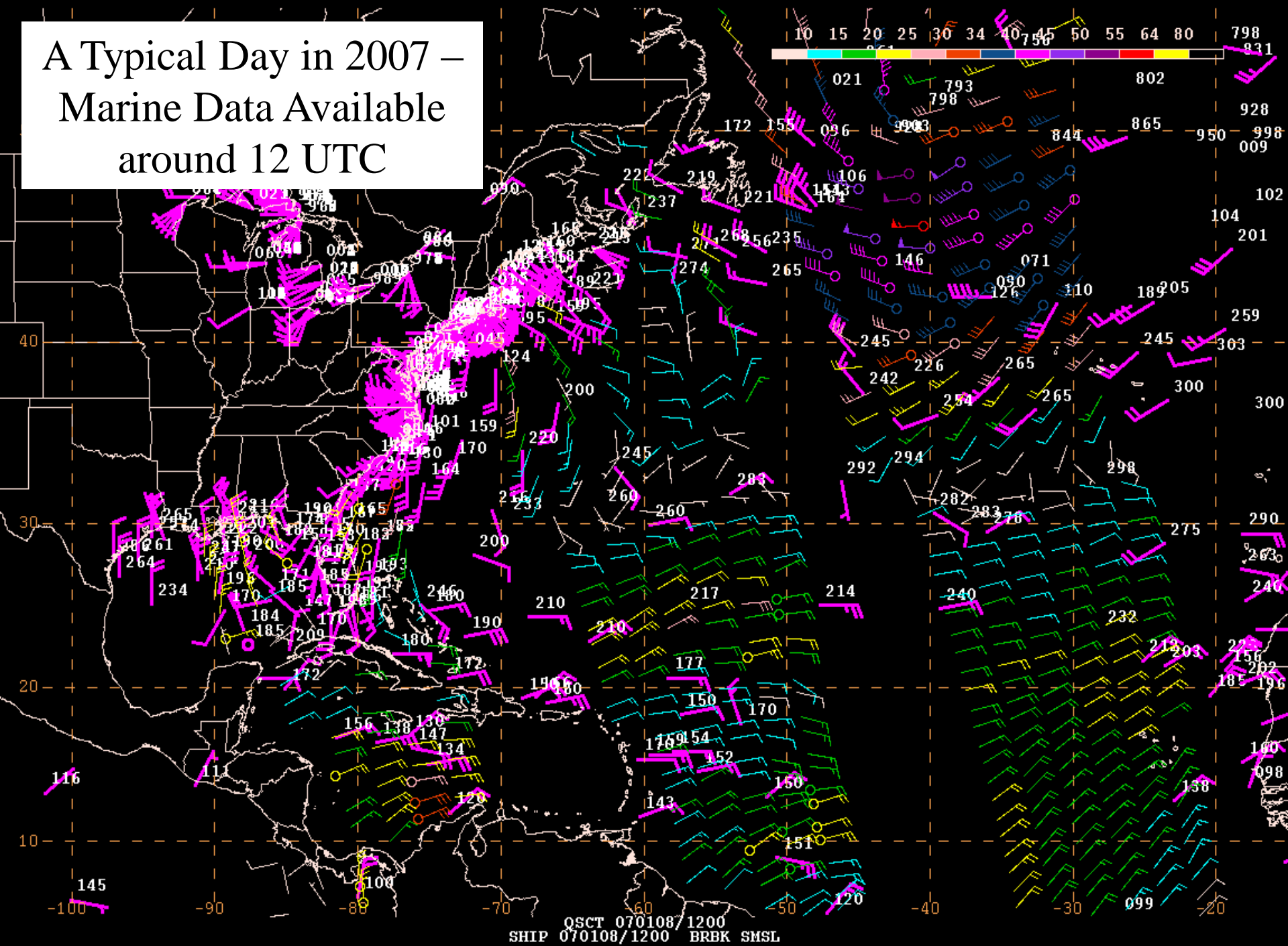
NUMBER	TYPE	NAME	DATE
14	H	NANETTE	5 Sep.-10 Sep.
15	H	PHILIA	6 Sep.-17 Sep.
16	H	PHILIPPE	17 Sep.-23 Sep.
17	H	RITA	18 Sep.-26 Sep.
18	H	STAN	1 Oct.-5 Oct.
19	ST	UNNAMED	4 Oct.-5 Oct.
20	T	TAMMY	5 Oct.-6 Oct.
21	H	VINCE	8 Oct.-11 Oct.
22	H	WILMA	15 Oct.-25 Oct.
23	T	ALPHA	22 Oct.-24 Oct.
24	H	BETA	26 Oct.-31 Oct.
25	T	GAMMA	14 Nov.-21 Nov.
26	T	DELTA	22 Nov.-28 Nov.
27	H	EPSILON	29 Nov.-8 Dec.
28	T	ZETA	30 Dec.-6 Jan. 2006

Open Atlantic
Ocean Differences

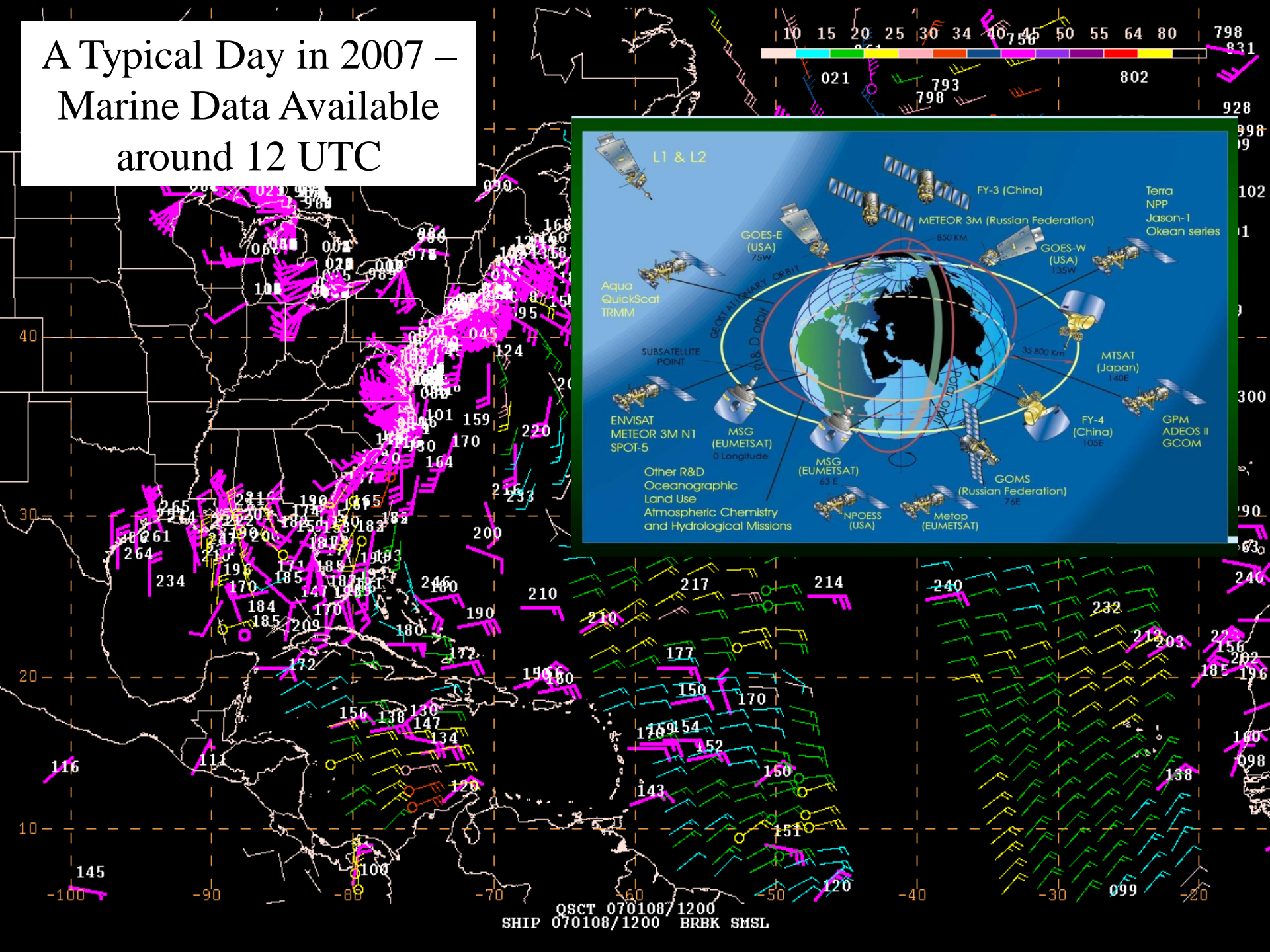
COMMERCE, WEATHER BUREAU
HURRICANE TRACKING CHART

1933 Hurricane Season

A Typical Day in 2007 – Marine Data Available around 12 UTC



A Typical Day in 2007 – Marine Data Available around 12 UTC

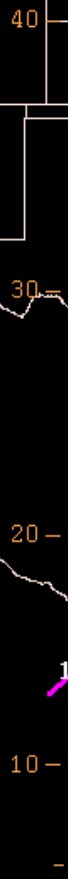


A Typical Day in 2007 –

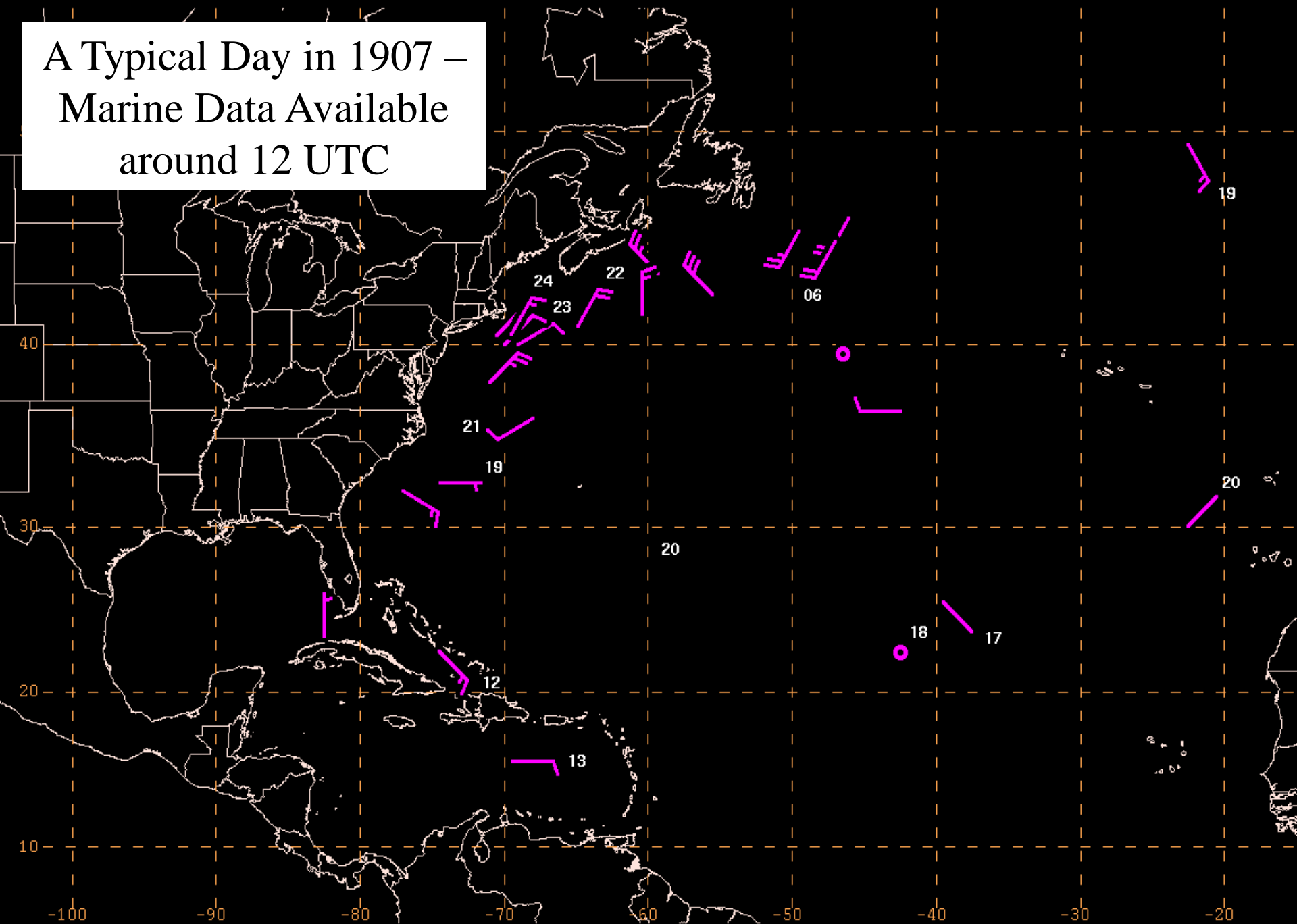
M



QOCT 070108/1200
SHIP 070108/1200 BRBK SMSL



A Typical Day in 1907 –
Marine Data Available
around 12 UTC



A Typical Day in 1007



40

30

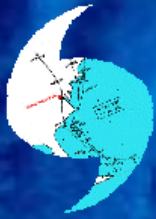
20

10

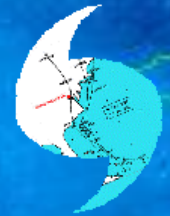
-100 -90 -80 -70 -60 -50 -40 -30 -20

Atlantic Hurricane Database Re-Analysis Project

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



1851 through 1920 changes accepted and officially adopted by NHC. 1921 through 1927 have been submitted to NHC. Remainder of 20th Century currently being reanalyzed.



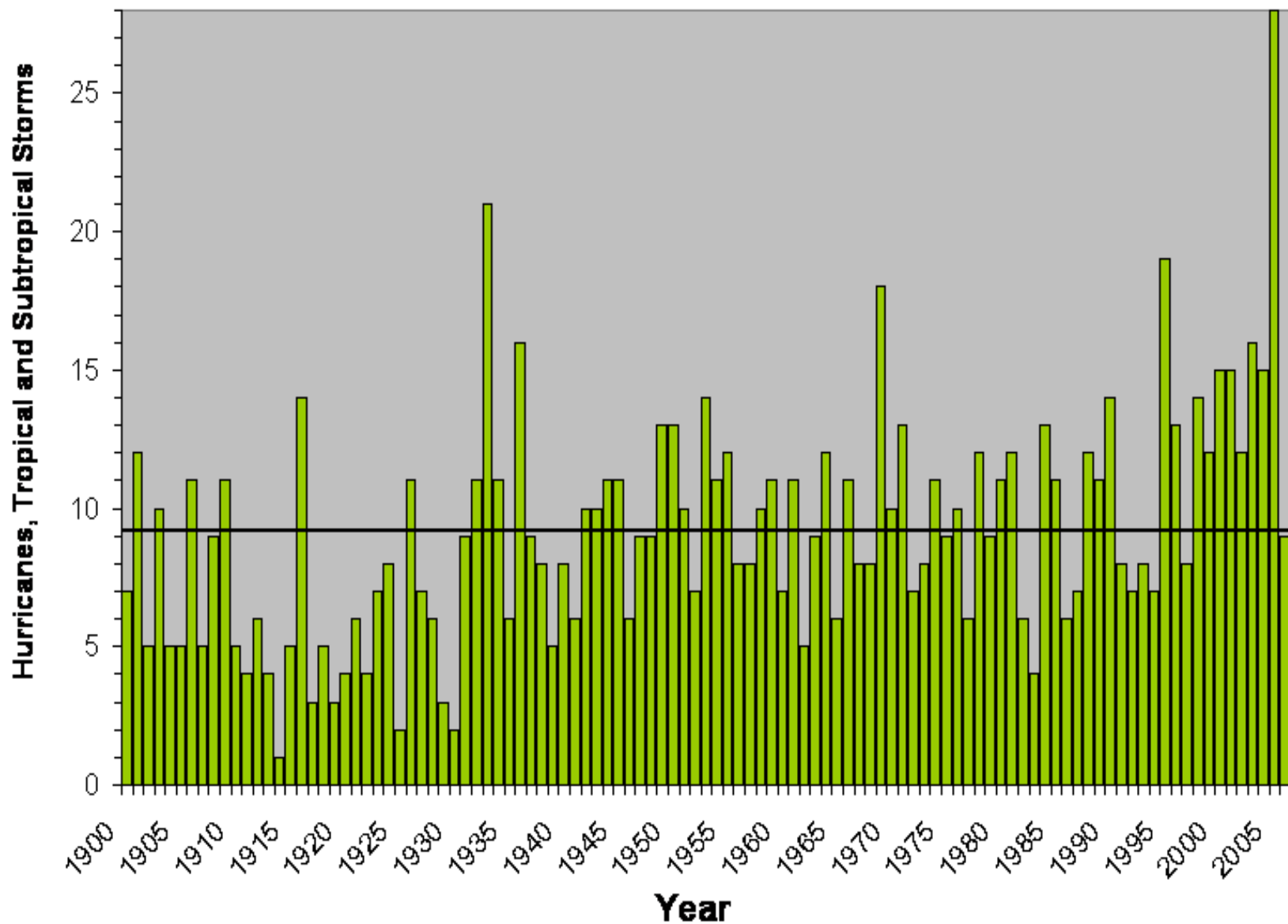
**RE-ANALYSES NEED TO BE CONDUCTED
GLOBALLY!!!**



"Florida's Hurricane History"

Atlantic Named Storms

1900 to 2006

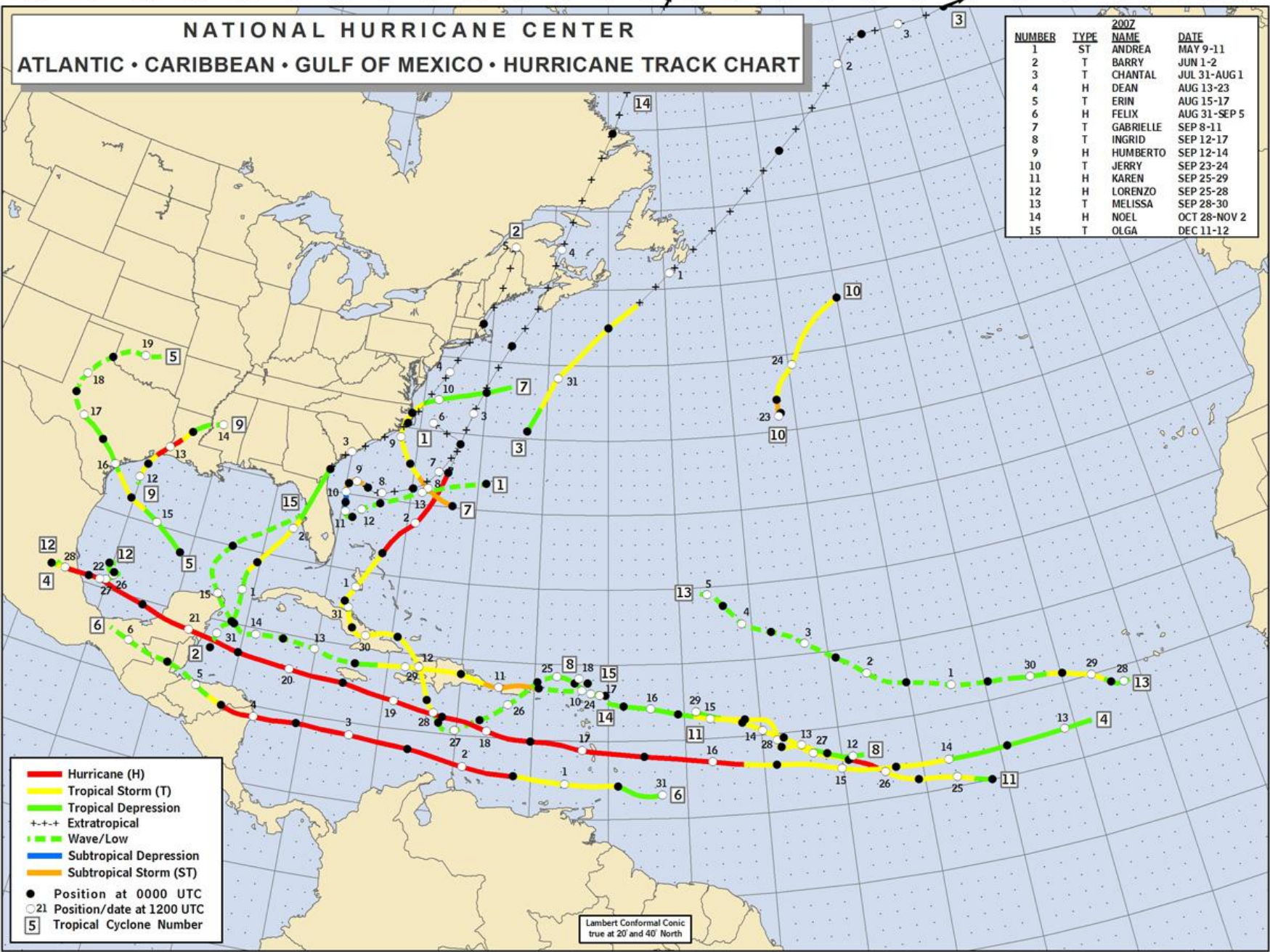


120° 115° 110° 105° 100° 95° 90° 85° 80° 75° 70° 65° 60° 55° 50° 45° 40° 35° 30° 25° 20° 15° 10° 5° West 0° East 5°

NATIONAL HURRICANE CENTER ATLANTIC • CARIBBEAN • GULF OF MEXICO • HURRICANE TRACK CHART

NUMBER	TYPE	2007 NAME	DATE
1	ST	ANDREA	MAY 9-11
2	T	BARRY	JUN 1-2
3	T	CHANTAL	JUL 31-AUG 1
4	H	DEAN	AUG 13-23
5	T	ERIN	AUG 15-17
6	H	FELIX	AUG 31-SEP 5
7	T	GABRIELLE	SEP 8-11
8	T	INGRID	SEP 12-17
9	H	HUMBERTO	SEP 12-14
10	T	JERRY	SEP 23-24
11	H	KAREN	SEP 25-29
12	H	LORENZO	SEP 25-28
13	T	MELISSA	SEP 28-30
14	H	NOEL	OCT 28-NOV 2
15	T	OLGA	DEC 11-12

- Hurricane (H)
- Tropical Storm (T)
- Tropical Depression
- +++ Extratropical
- Wave/Low
- Subtropical Depression
- Subtropical Storm (ST)
- Position at 0000 UTC
- 21 Position/date at 1200 UTC
- 5 Tropical Cyclone Number



Lambert Conformal Conic true at 20° and 40° North

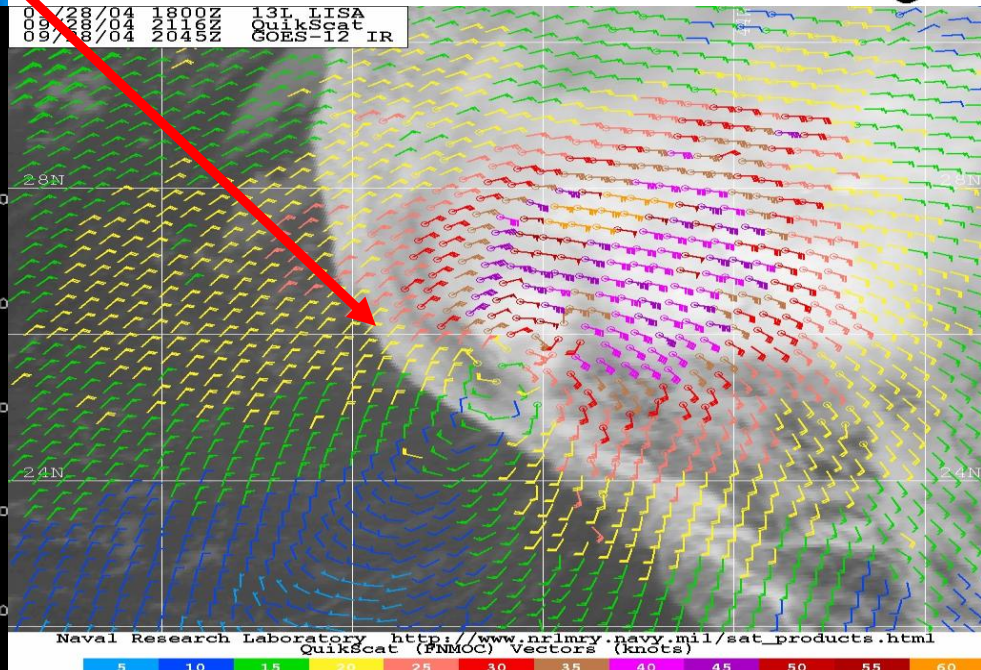
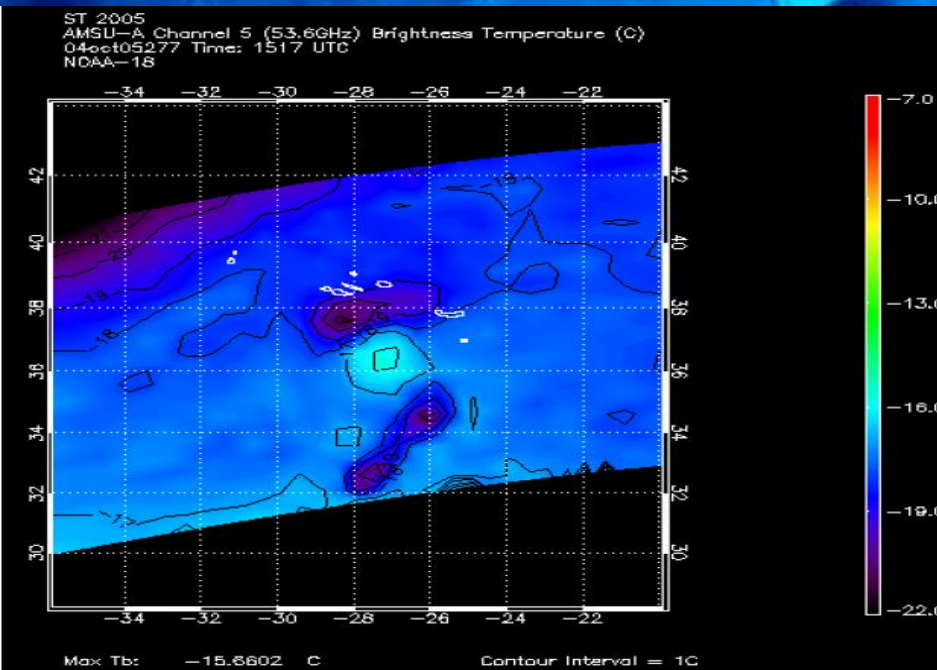
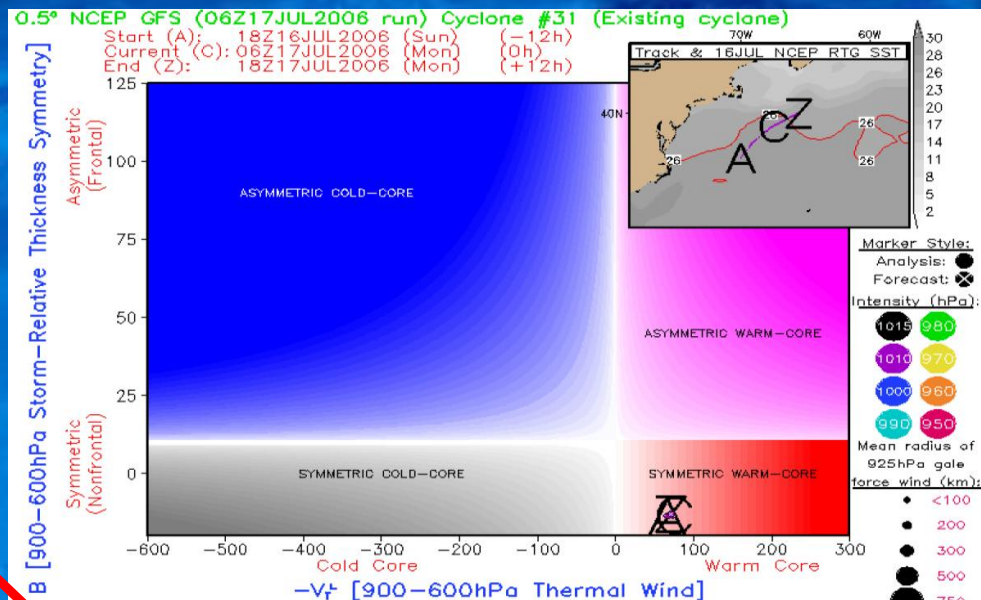
North
South

New Tools and Technologies ~ Additional TCs recently?

Hart's Cyclone Phase
Space Analyses

Quikscat Surface
Vectors

AMSU Tropospheric
Temperatures





Changes in “Naming” Criteria

“If it was quite marginal as to whether or not a storm would be upgraded to tropical storm status or equivalent, that decision would likely be influenced by proximity to possible impacts on land within the next 48 hours or so. That is, I suspect that the margin of acceptable error for most of us would be a little larger over the open sea as compared to potential landfall for such storms that are not all that strong anyway.”

Bob Sheets, National Hurricane Center Director, 1987-1995

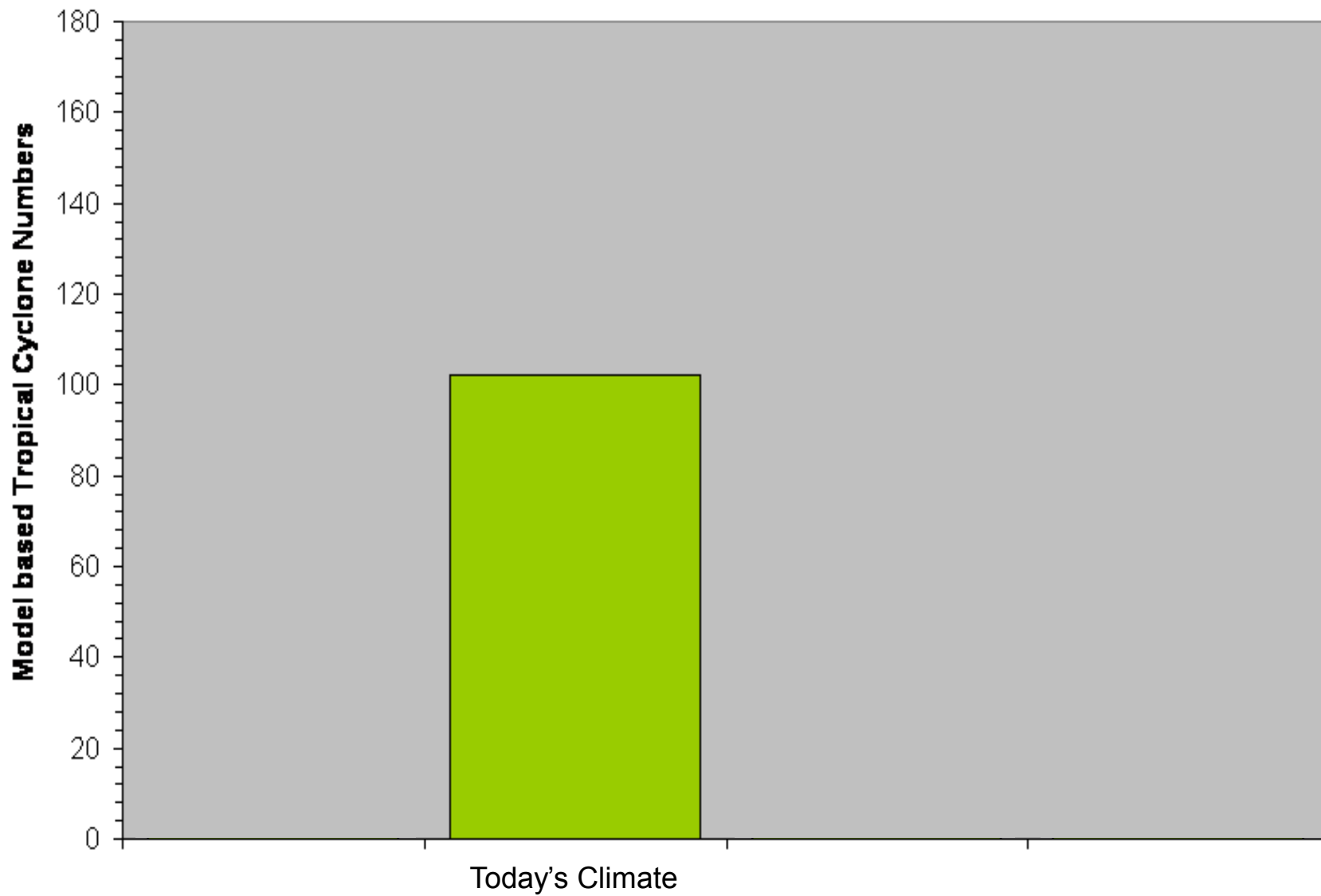


Changes in “Naming” Criteria

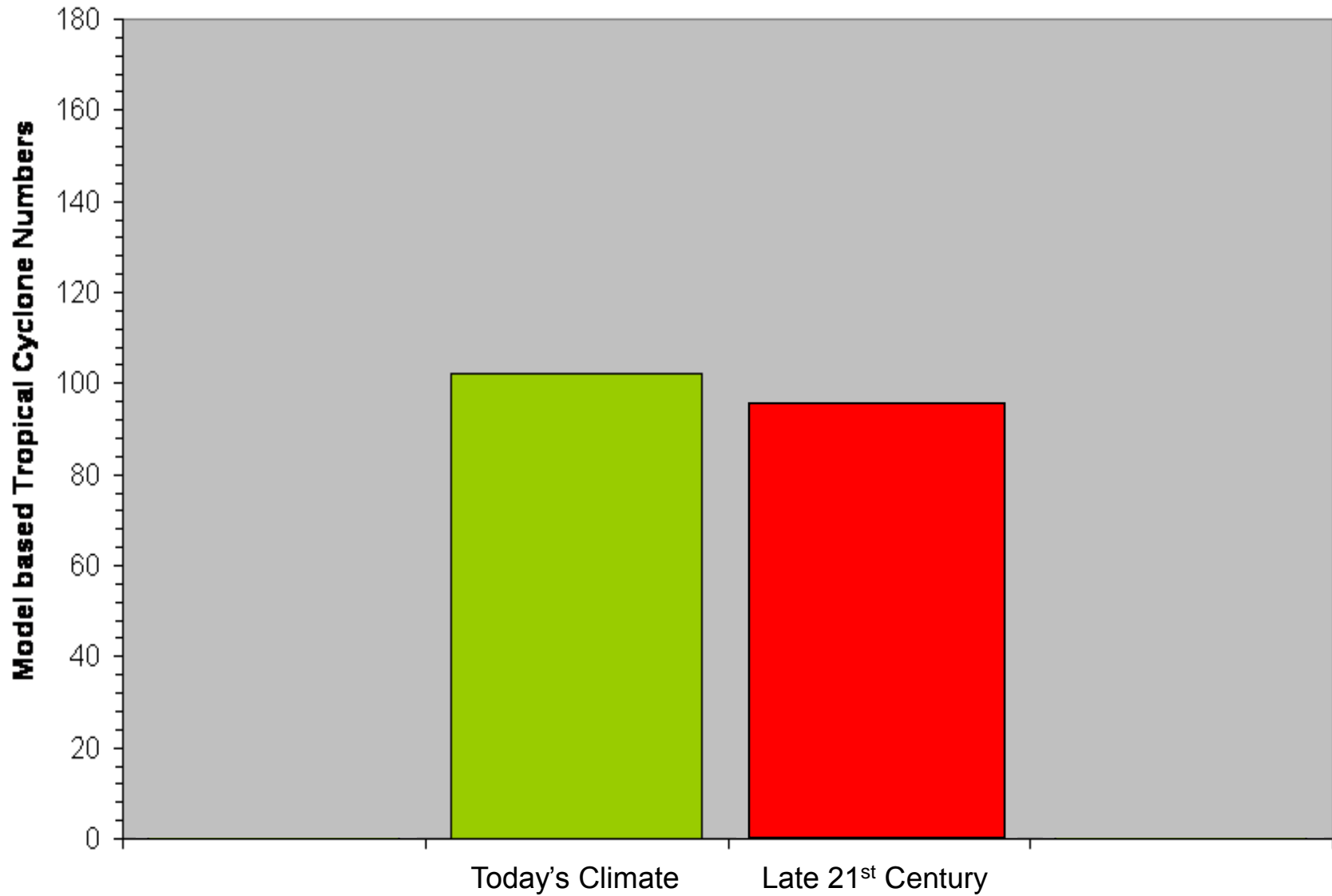
““[The National Hurricane Center] seems to be naming a lot more than they used to. This year, I would put four storms in the very questionable category, and maybe even six. In the past, we would have waited to see if another observation supported naming the system. We would have been a little more conservative.”

Neil Frank, National Hurricane Center Director, 1974-1987

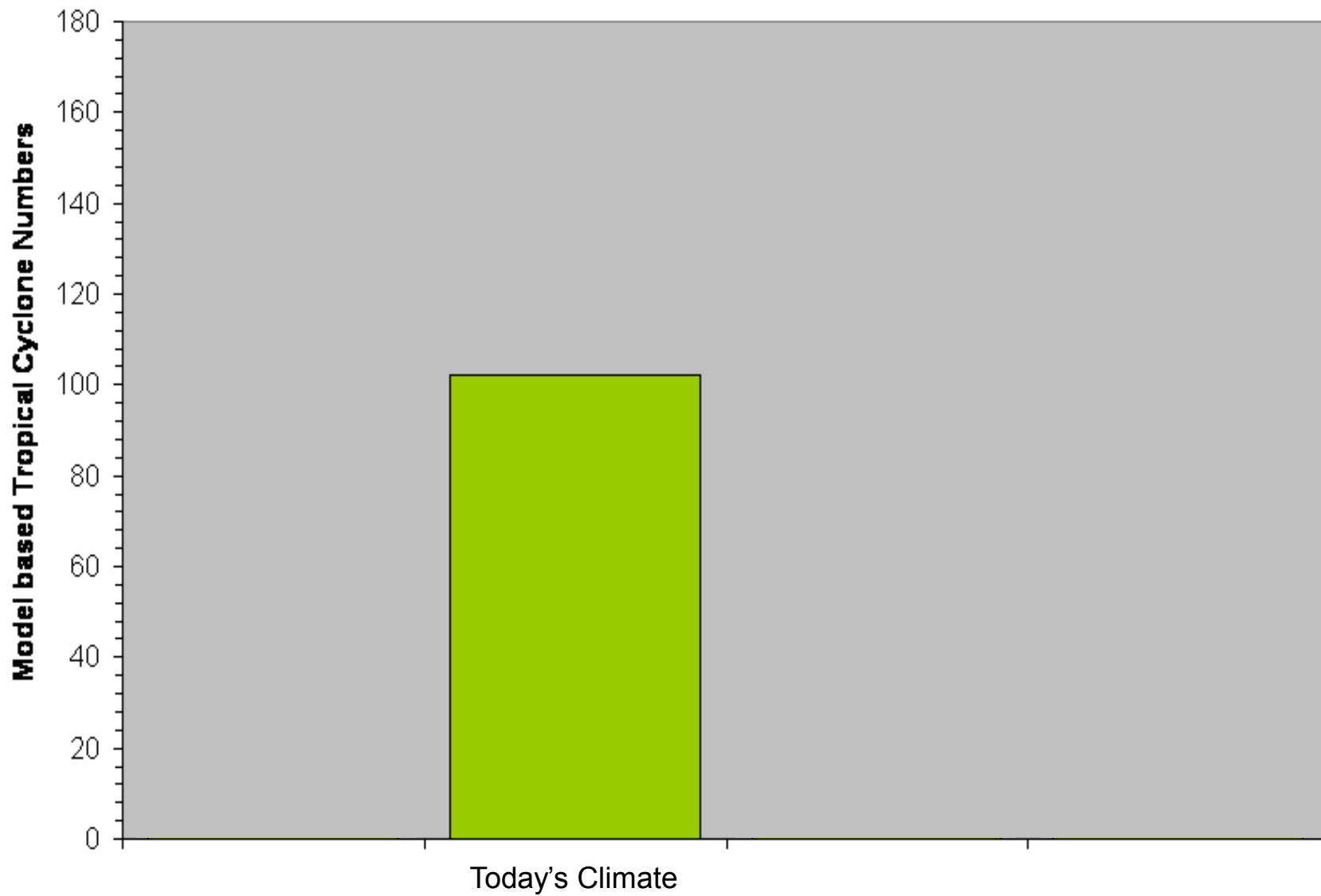
Frequency of Tropical Cyclones in Today's Climate



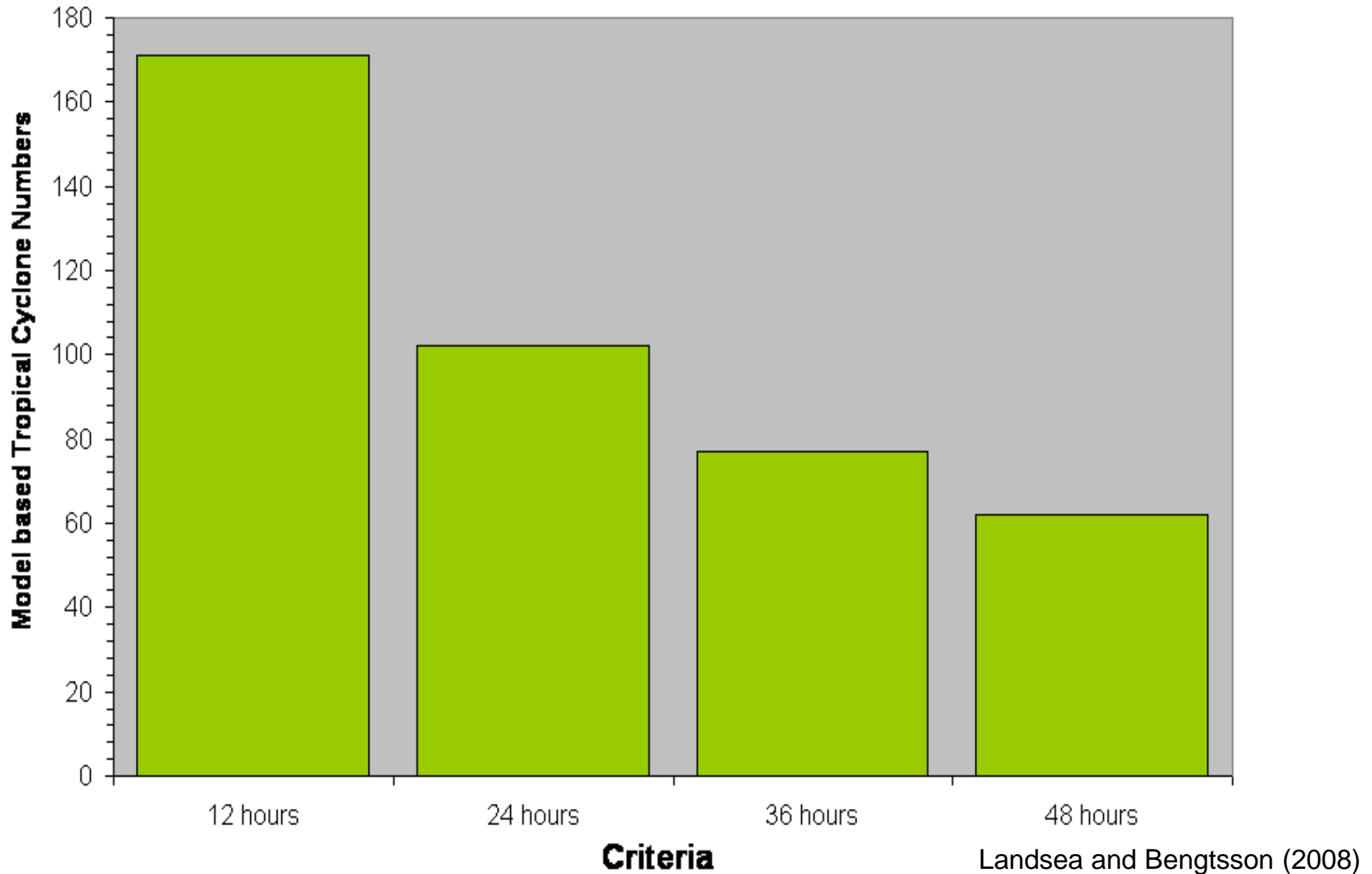
Frequency of Tropical Cyclones in Today's Climate Versus Global Warming Climate



Frequency of Tropical Cyclones in Today's Climate

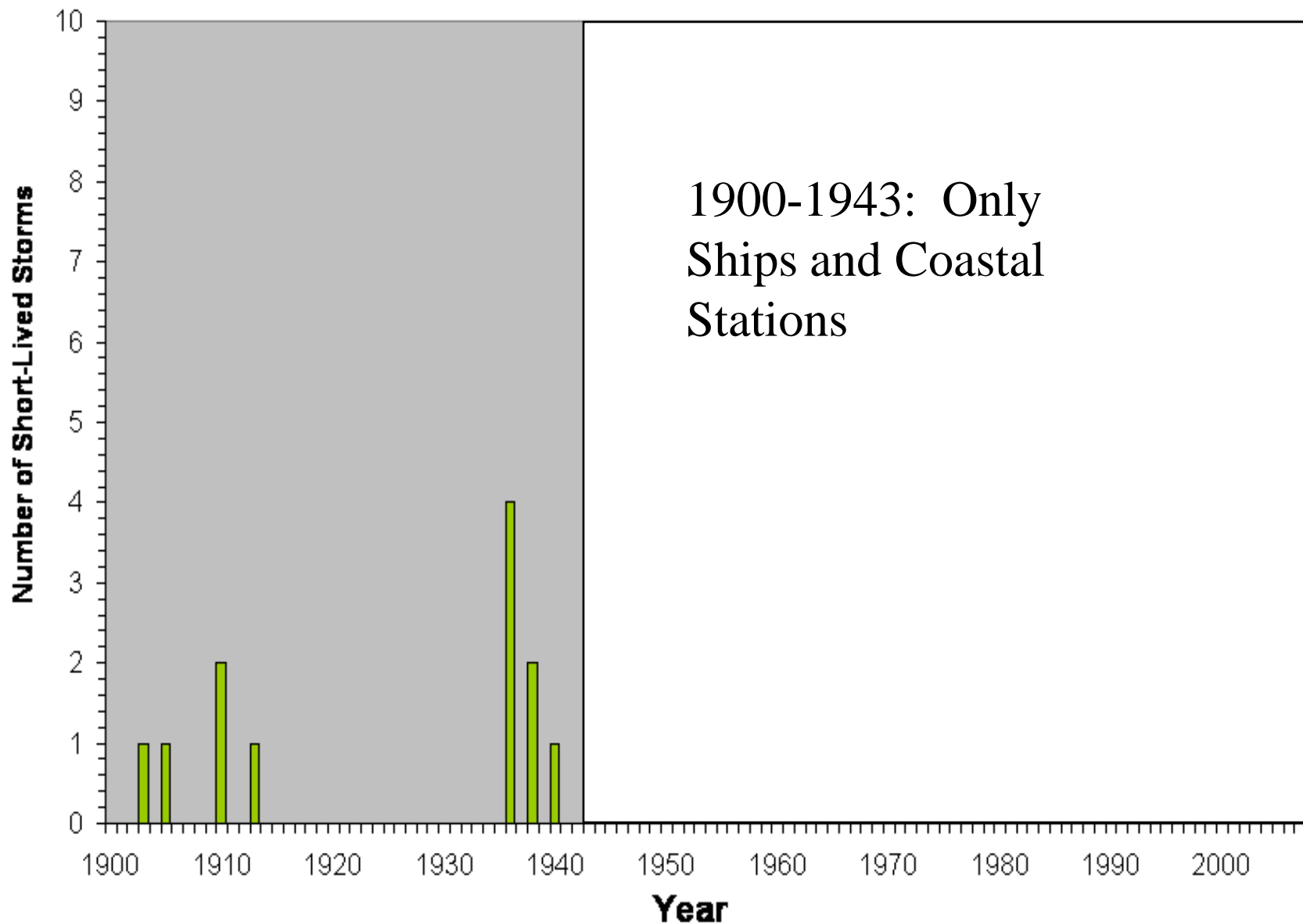


Frequency of Tropical Cyclones in Today's Climate ...Based upon Differing Thresholds of Duration



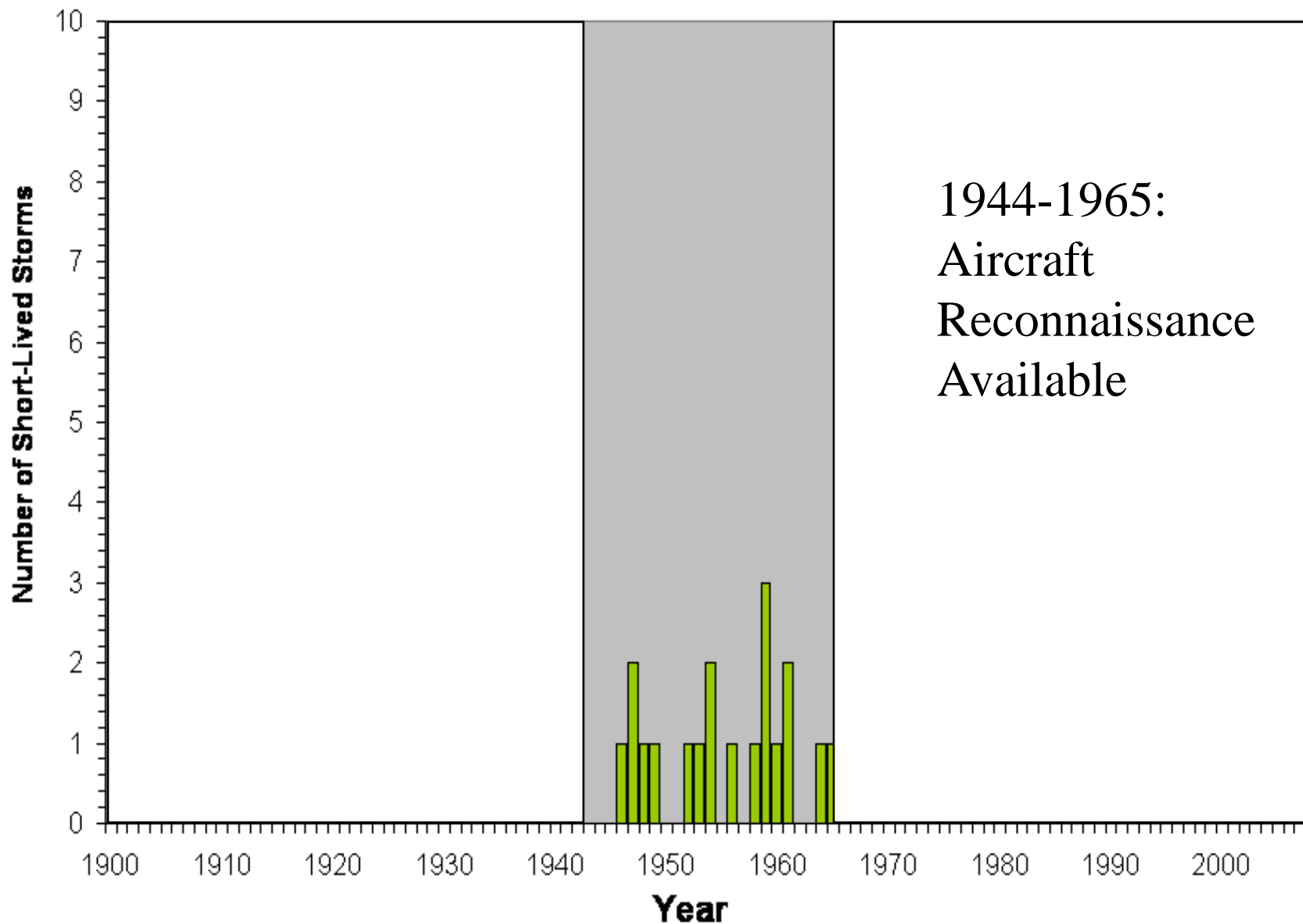
Short-Lived Atlantic Tropical Cyclones

1900-2007 1.5 Days or Less as Named Storm



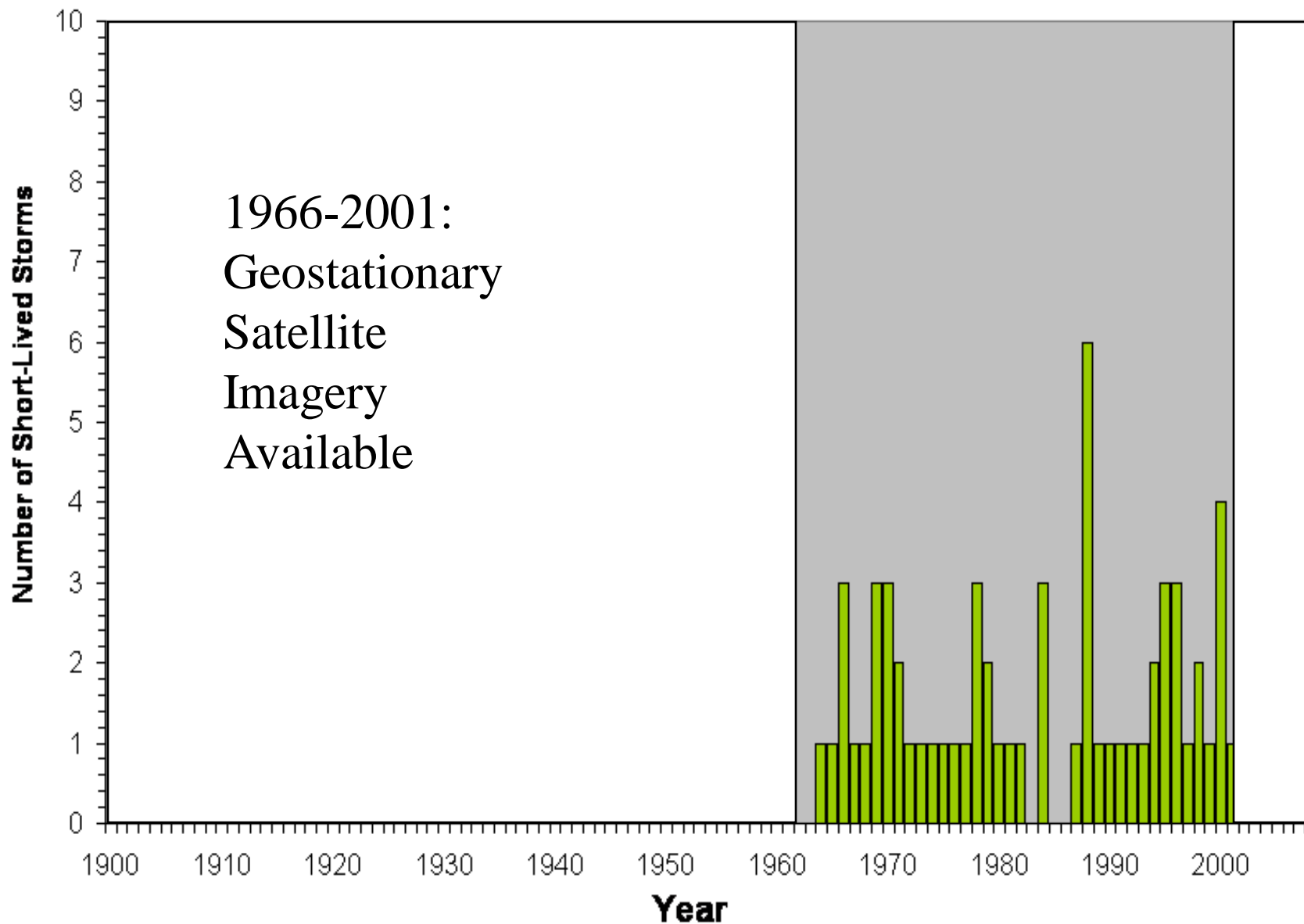
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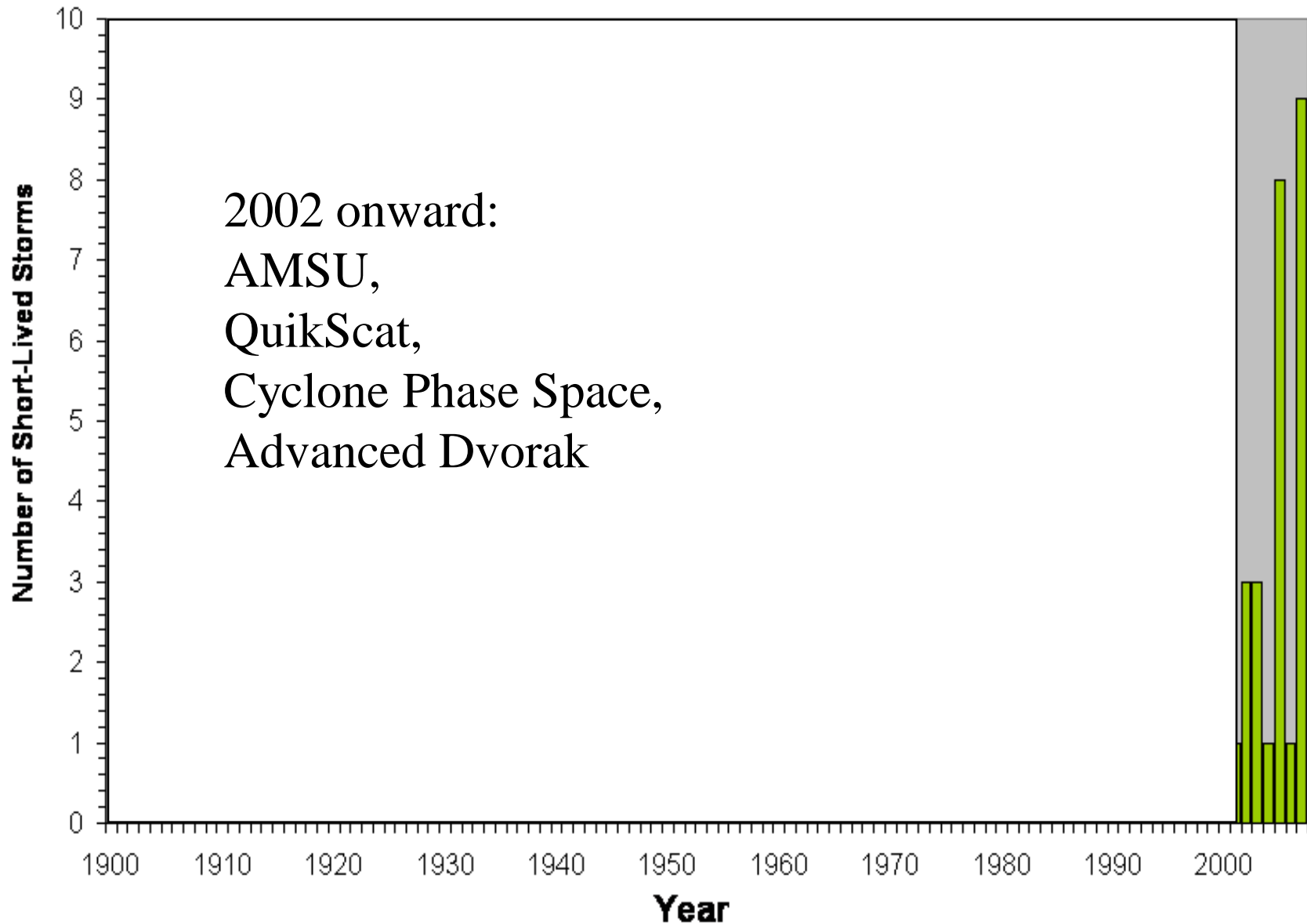
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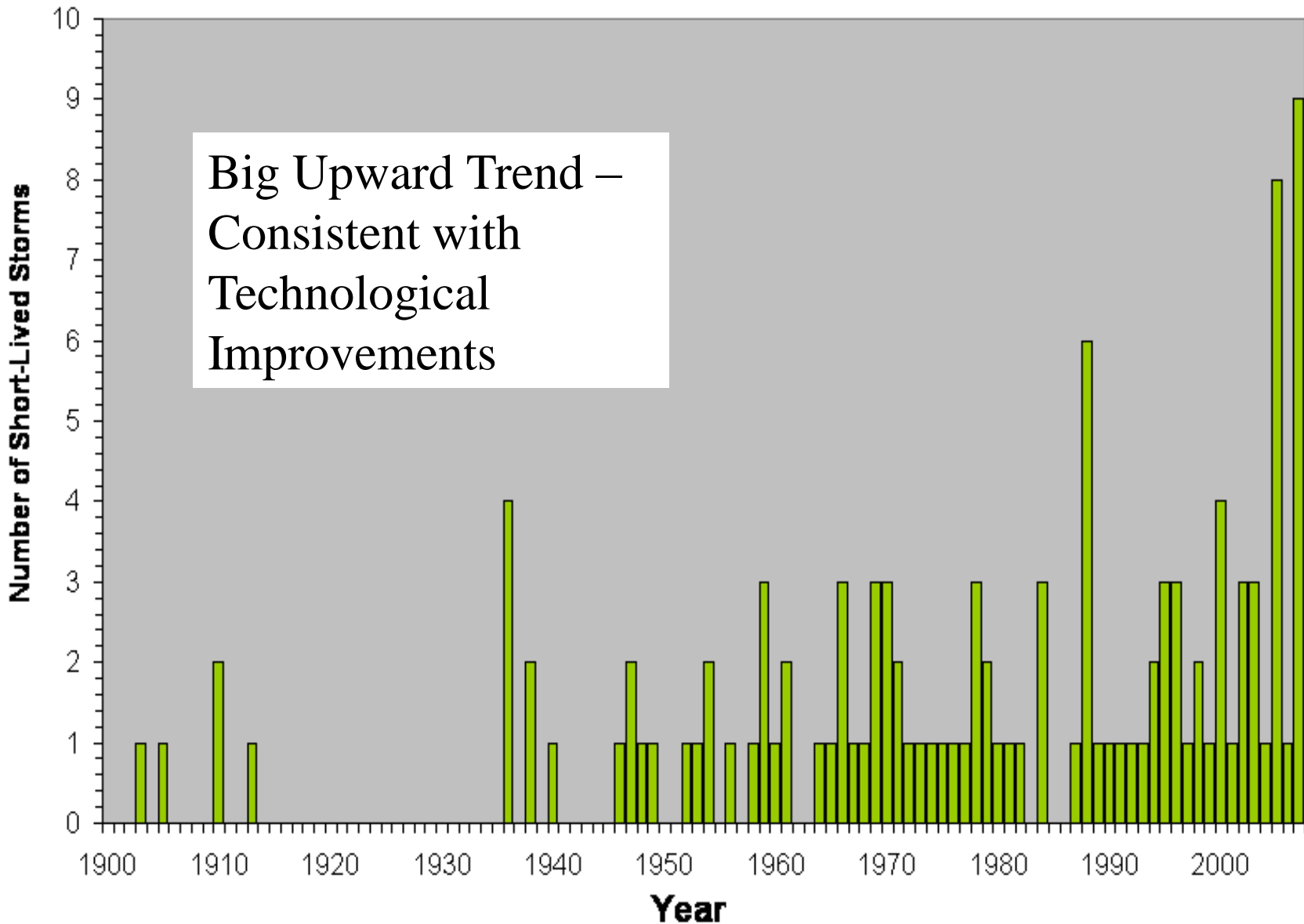
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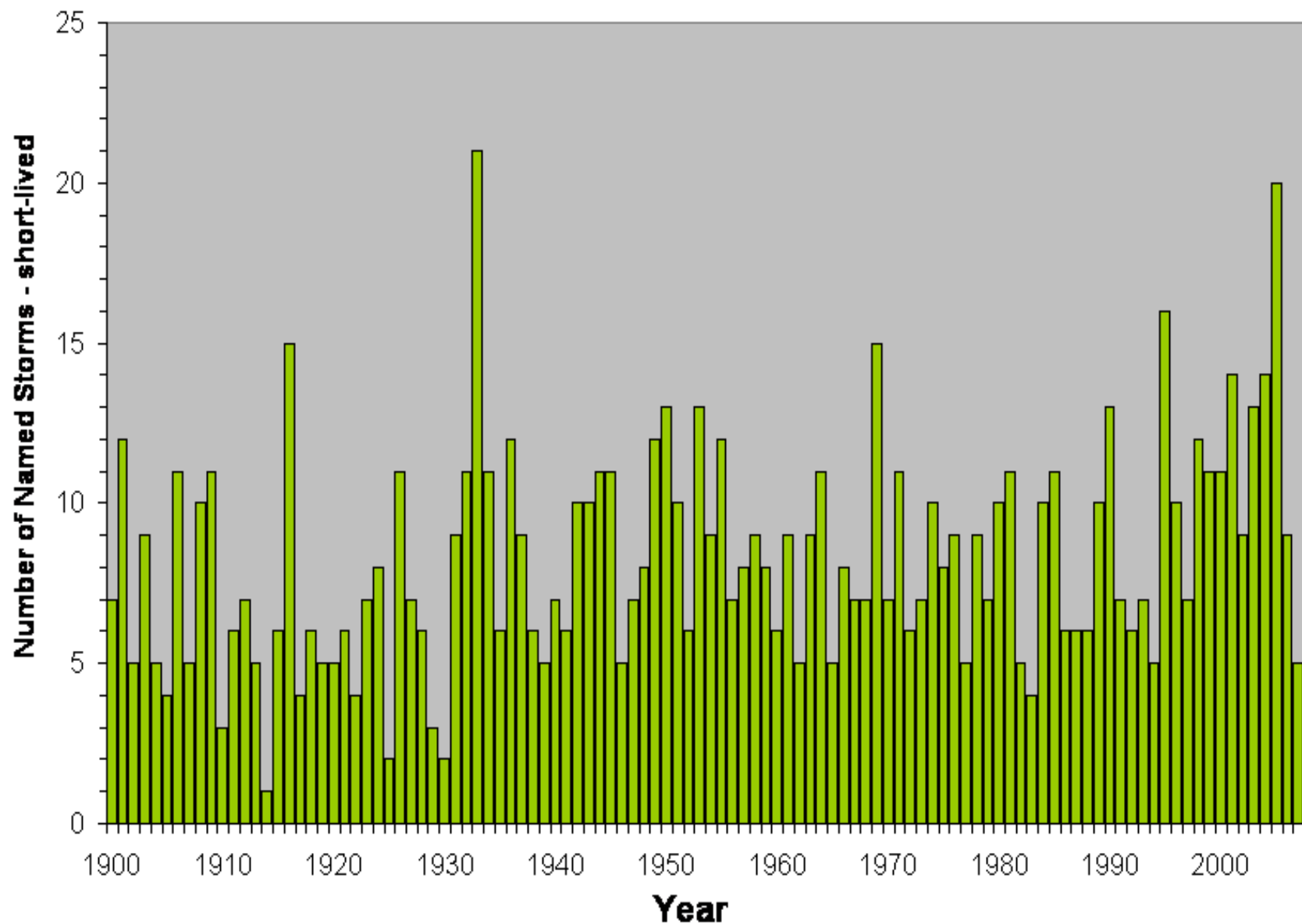
Short-Lived Atlantic Tropical Cyclones

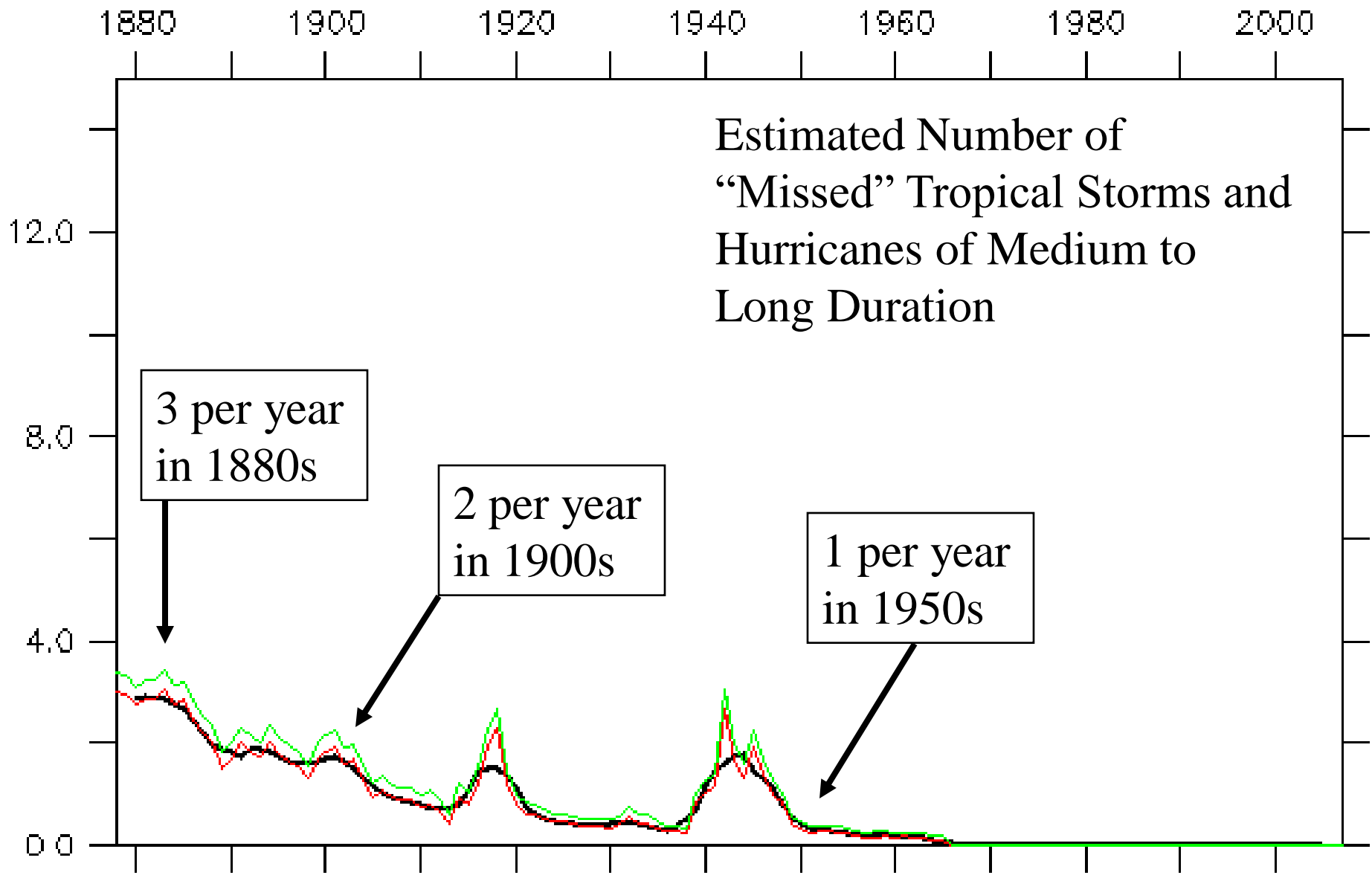
1900-2007 1.5 Days or Less as Named Storm



Atlantic Tropical Cyclones - Short-Lived

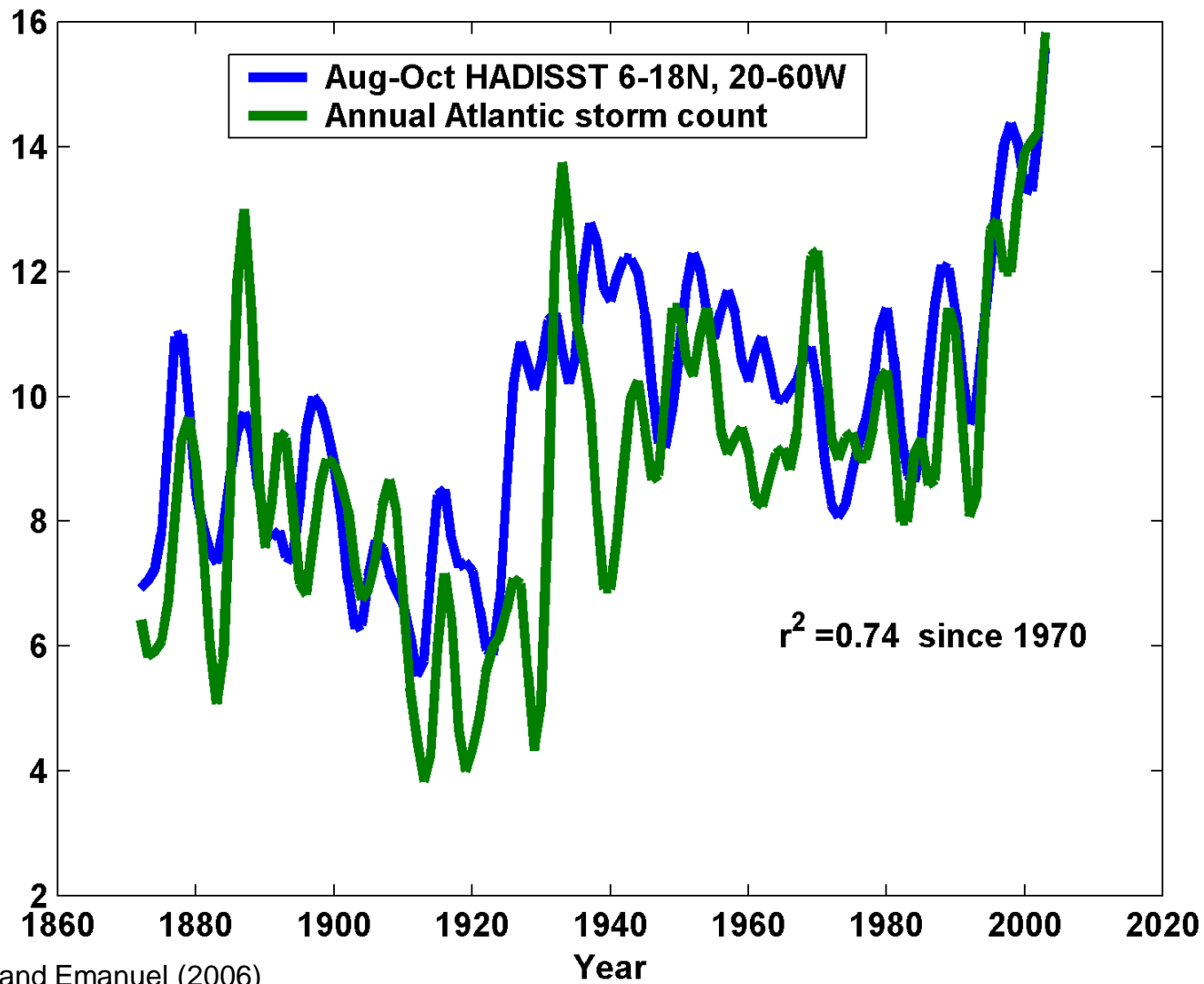
1900-2007 Named Storms



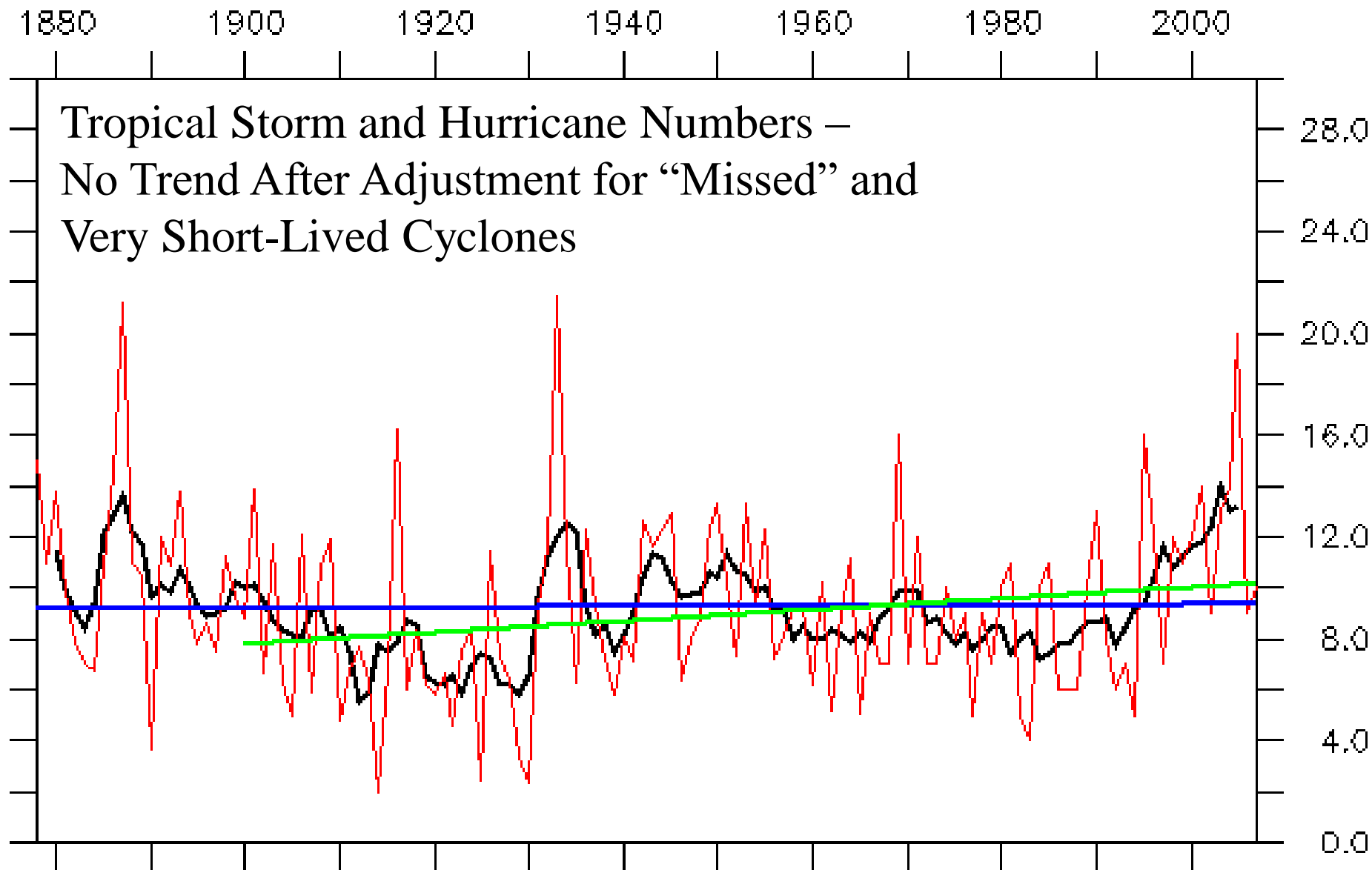


Annual and **5-Year** VK08 Adj. to TS (dur GT 1.5dy)
VK08 Adjustment to all storms

Linking frequency of Atlantic tropical cyclones to SSTs

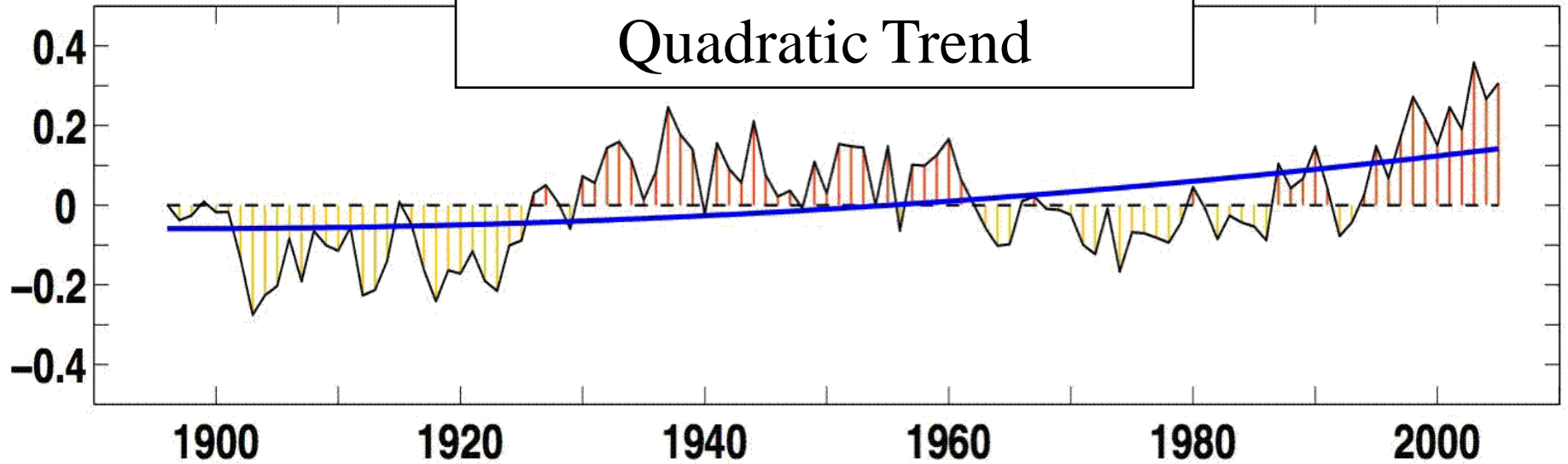


Mann and Emanuel (2006)

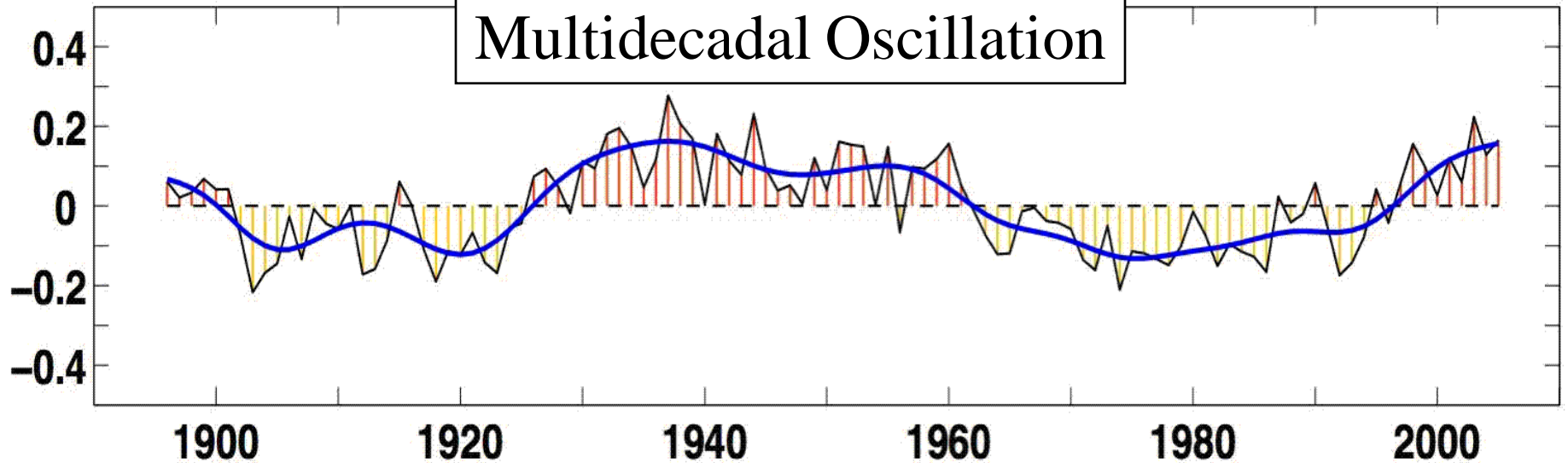


Annual and 5-Year TS (dur GT 1.5dy) – VK08 Adjusted

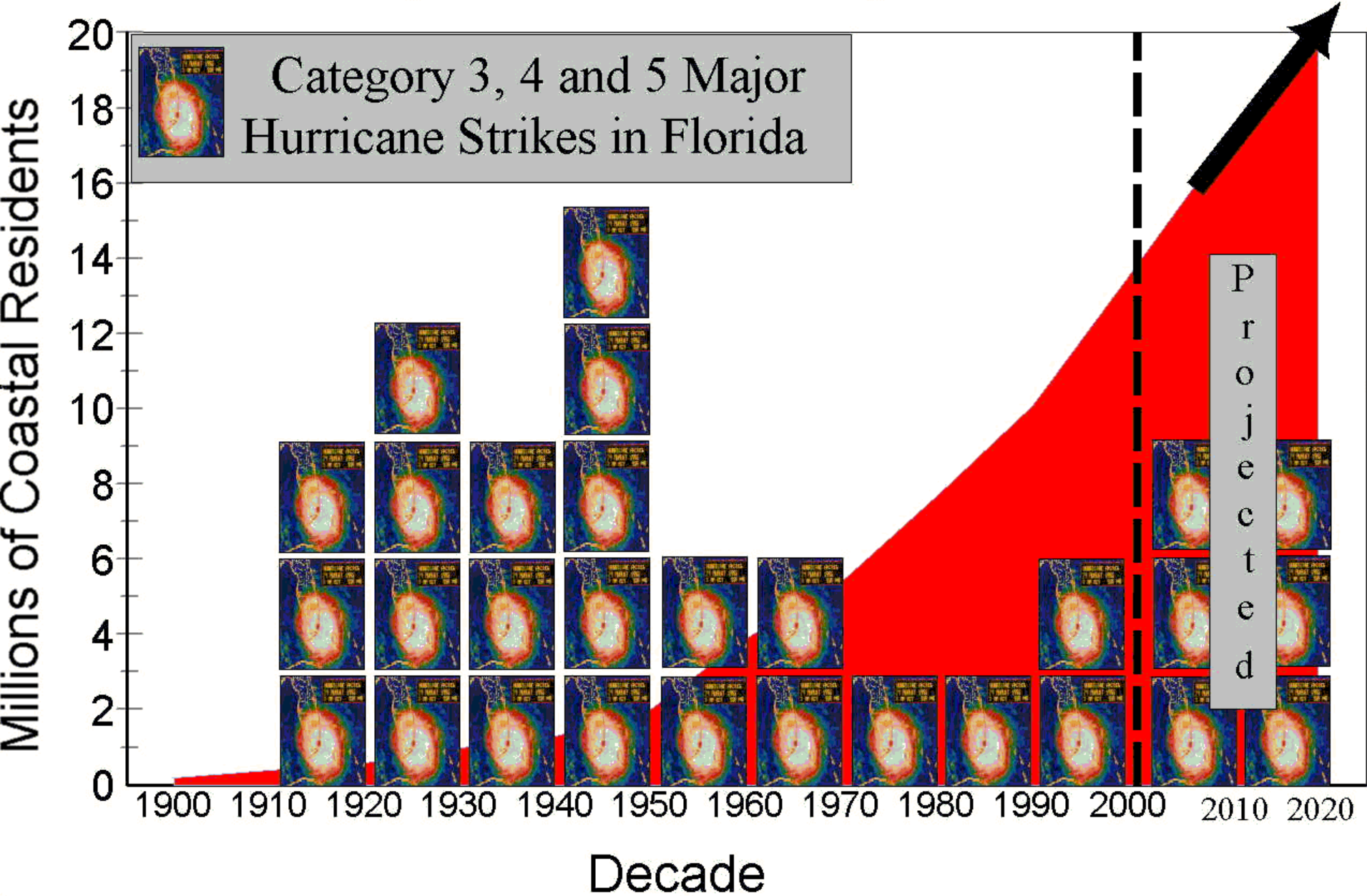
North Atlantic SSTs and Quadratic Trend



Residual Atlantic Multidecadal Oscillation



Florida Population and Major Hurricanes





AGGRESSIVE

188 lb/cm

NURSE



2005

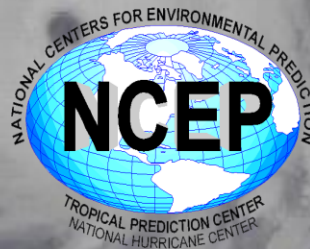
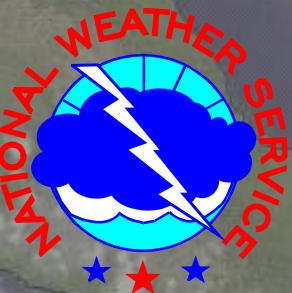
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