

2005
**Hurricanes and Climate Change:
 Expectations versus Observations**

Rita
23 September

6 August, 2009

Broward County Climate Change Task Force

Chris Landsea, National Hurricane Center, Miami, USA

28 August

Wilma
21 October

Dennis
10 July

**How is global warming affecting:
 Tropical cyclone frequency, intensity,
 genesis, track, overall activity?**



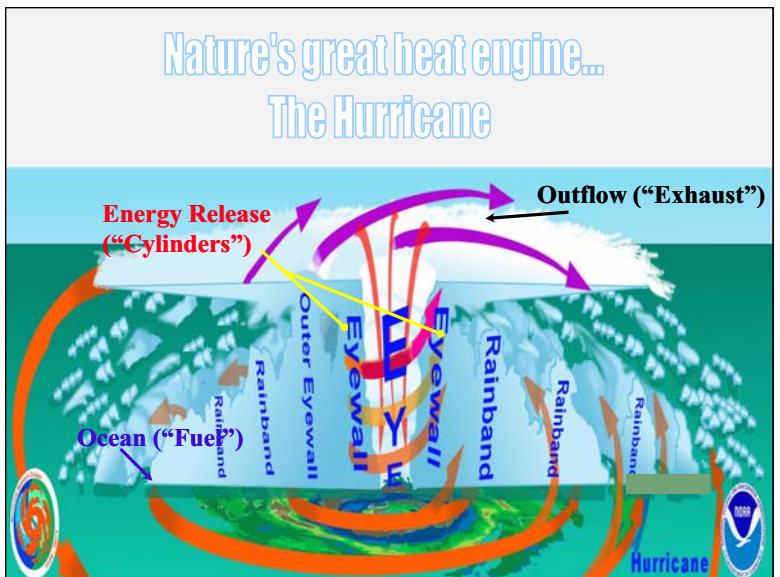
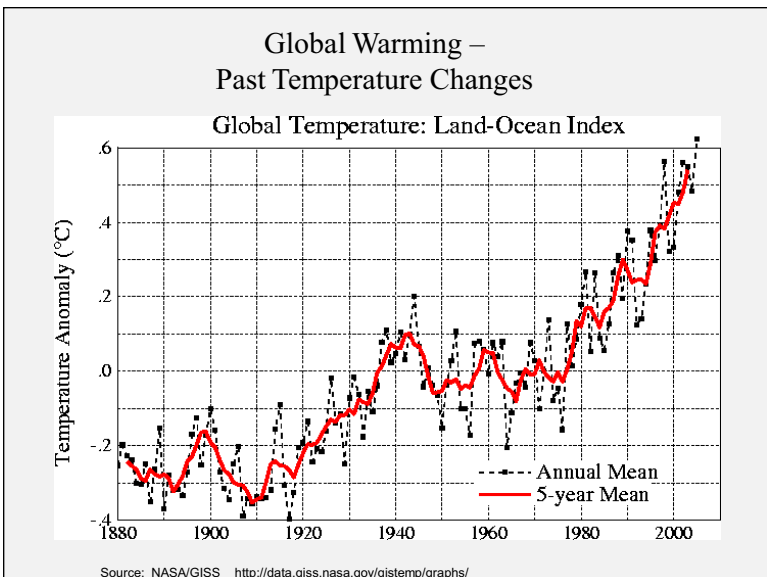
Before Katrina...

David & Kimberly King
 Waveland, MS

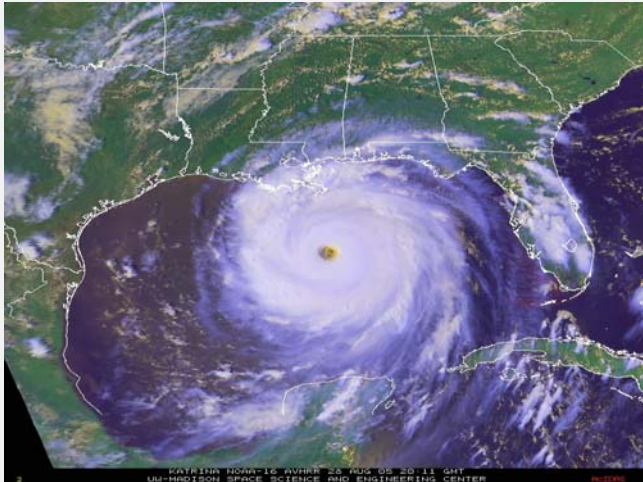


...After Katrina

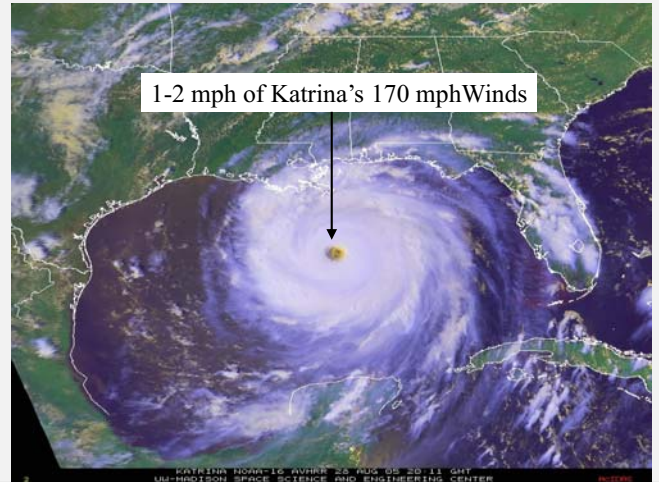
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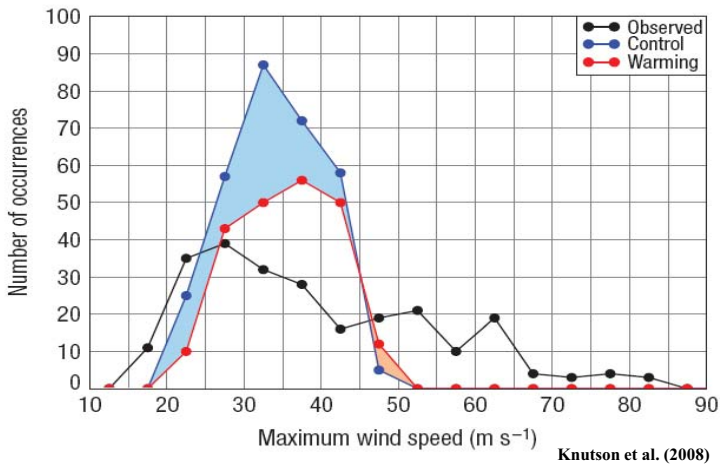
Global Warming and Hurricane Winds:
Theory and Modeling Work Suggest ~1% Increase Today



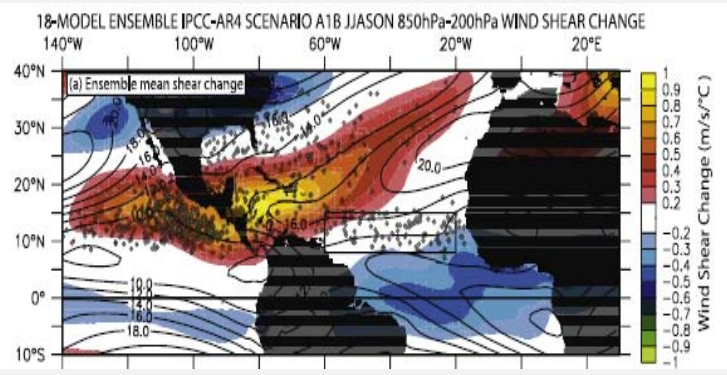
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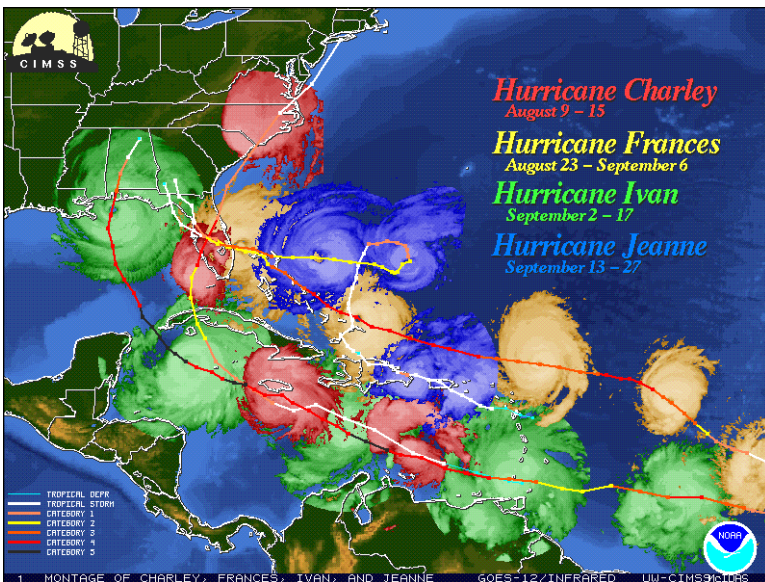
Global Warming and Hurricanes:
Theory and Modeling Work Suggest 4% wind increase with a
DECREASE in frequency by late 21st Century



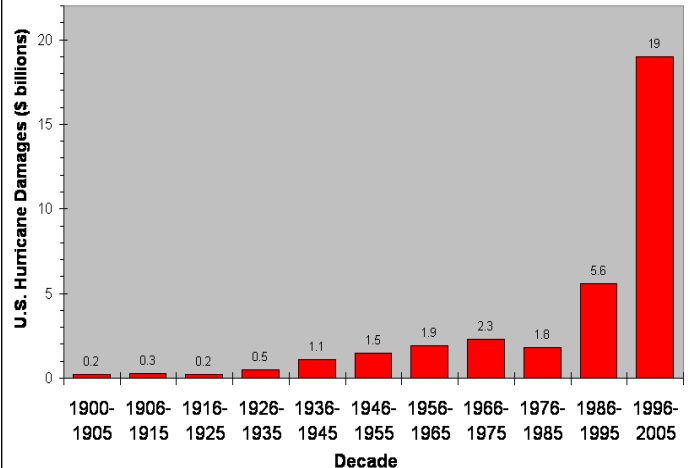
Increased Wind Shear from Global Warming



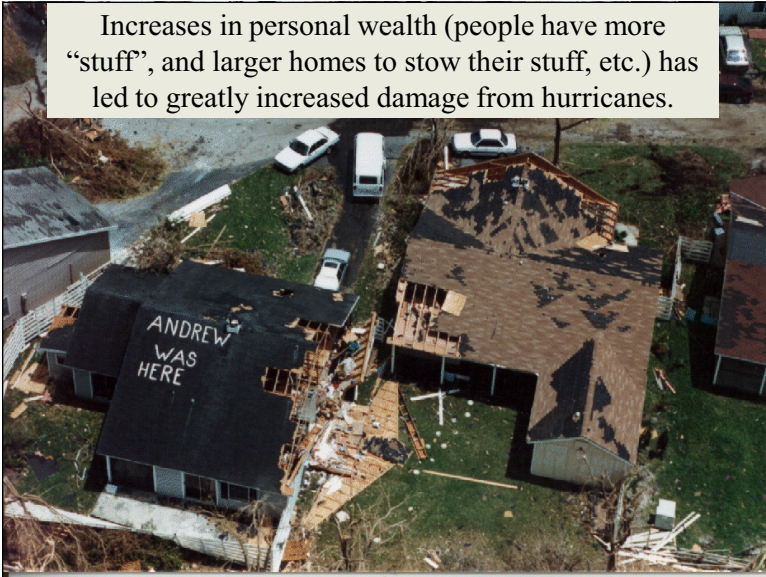
Vecchi and Soden (2007)



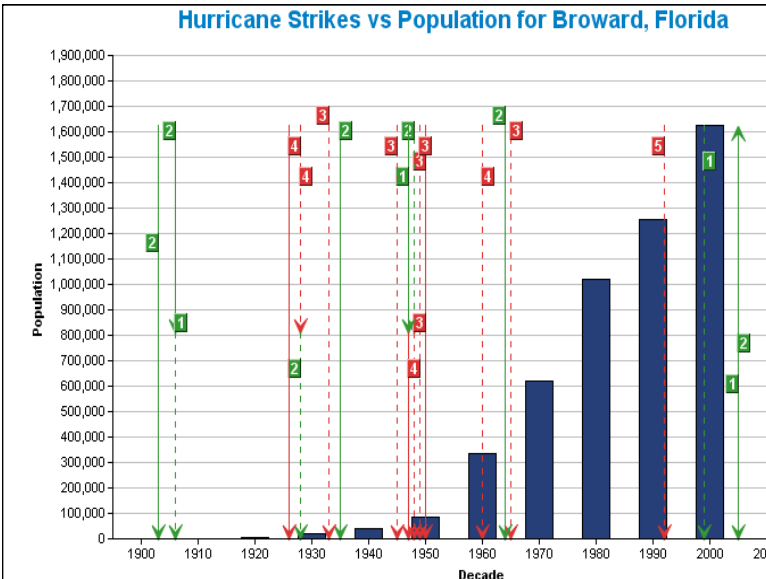
U.S. Tropical Storm and Hurricane Damages
\$BILLIONS Annually - Inflation Adjusted



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



Hurricane Strikes vs Population for Broward, 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



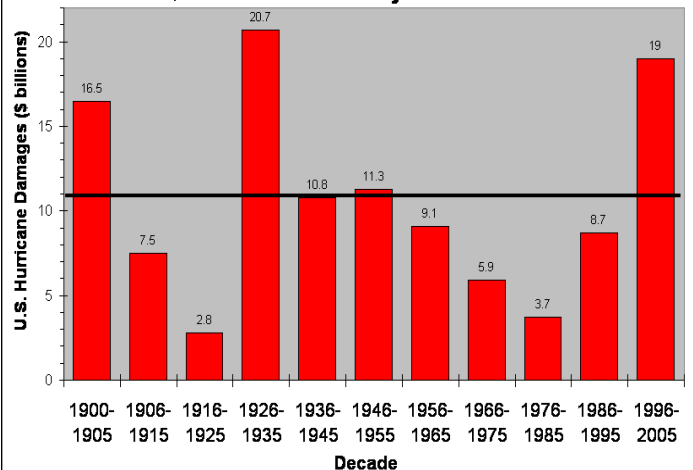
Miami Beach 2006

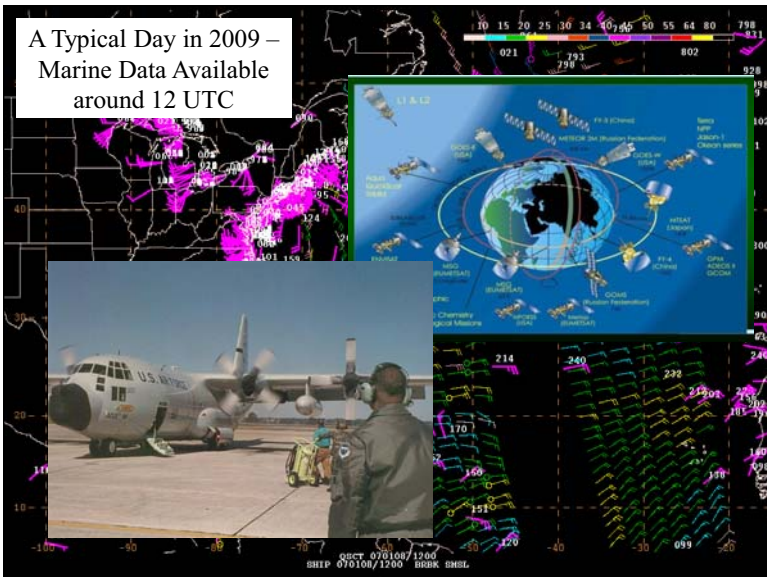
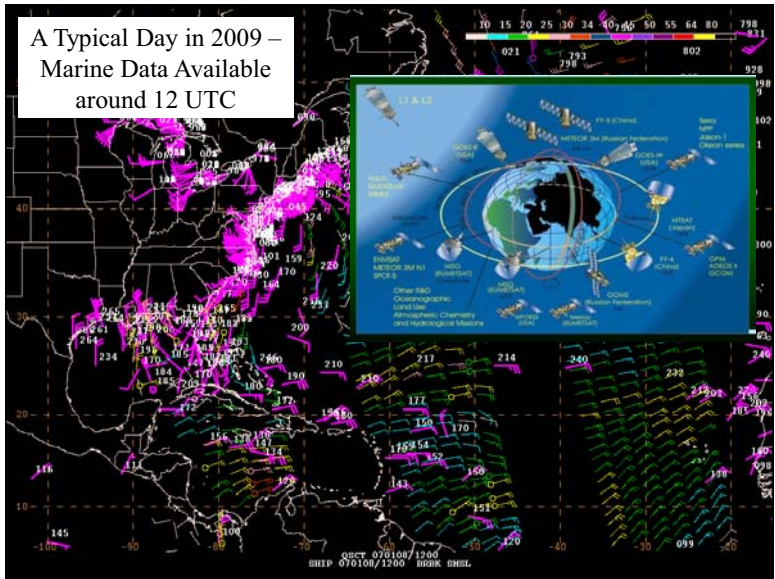
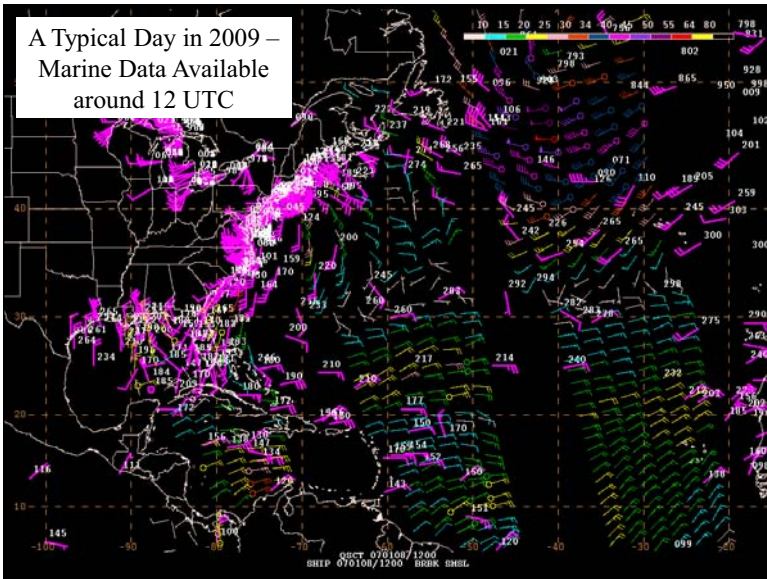
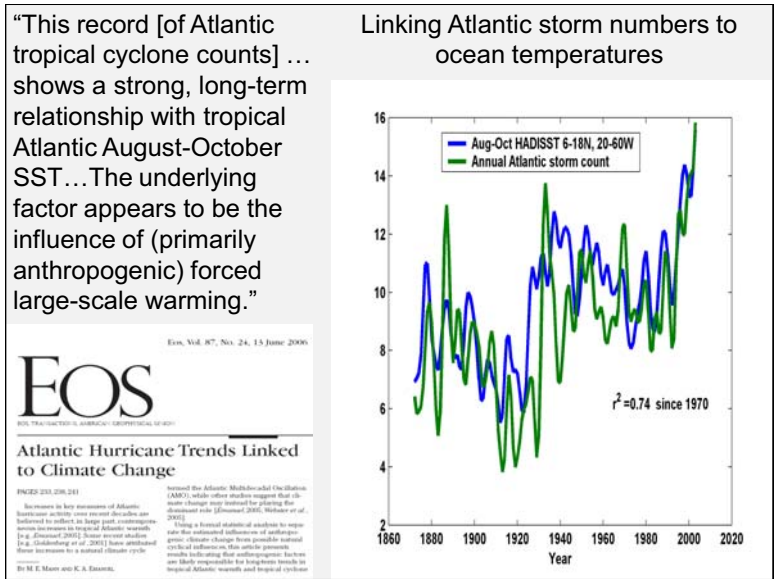
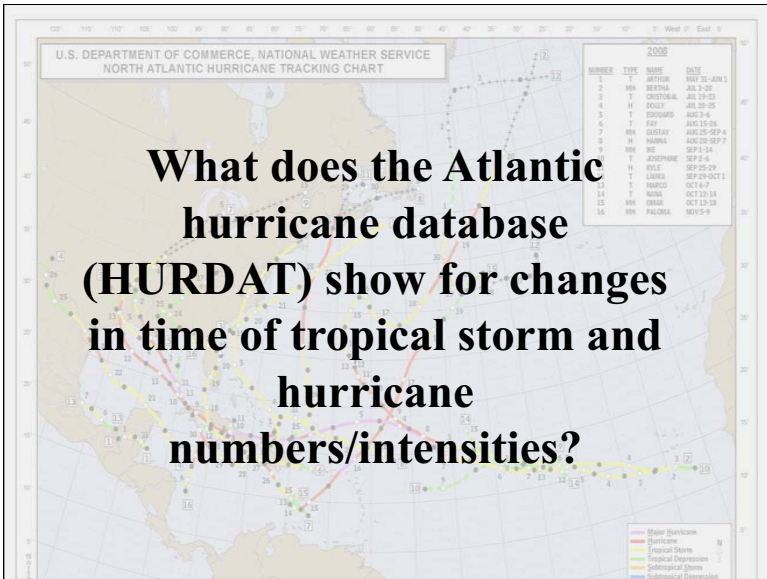


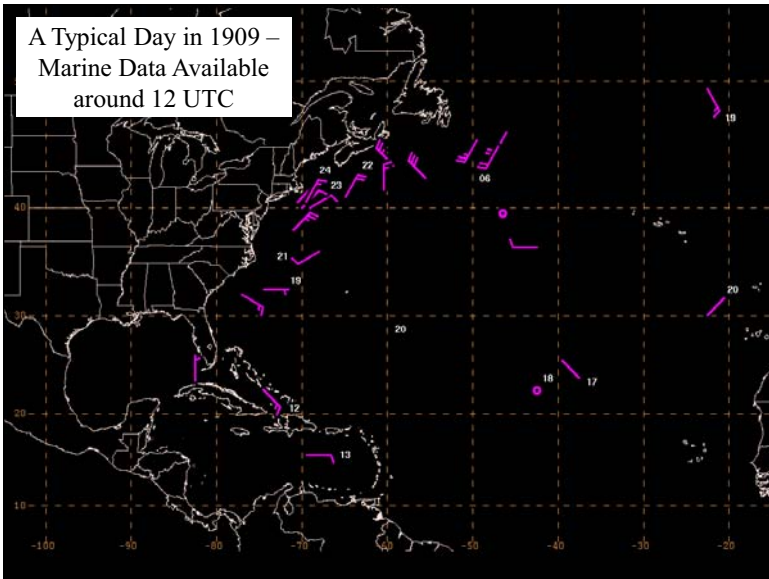
Wendler Collection

Joel Gratz © 2006

U.S. Tropical Storm and Hurricane Damages
\$BILLIONS Annually - Normalized





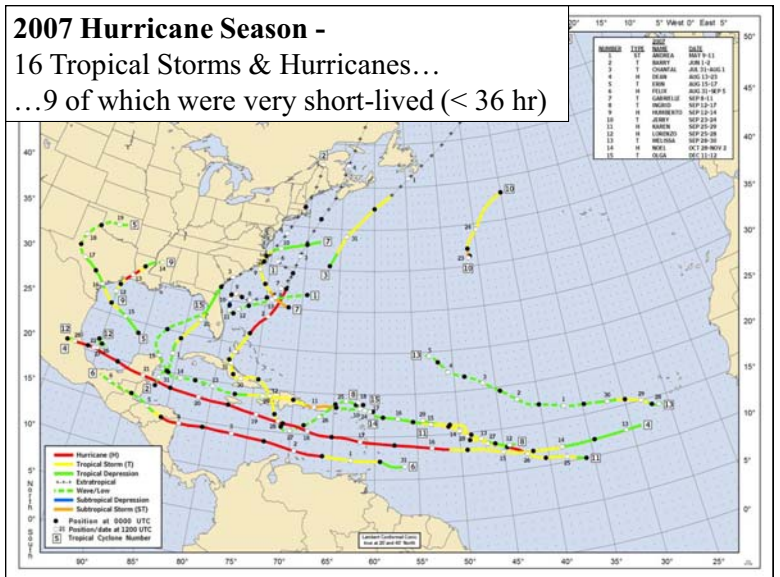
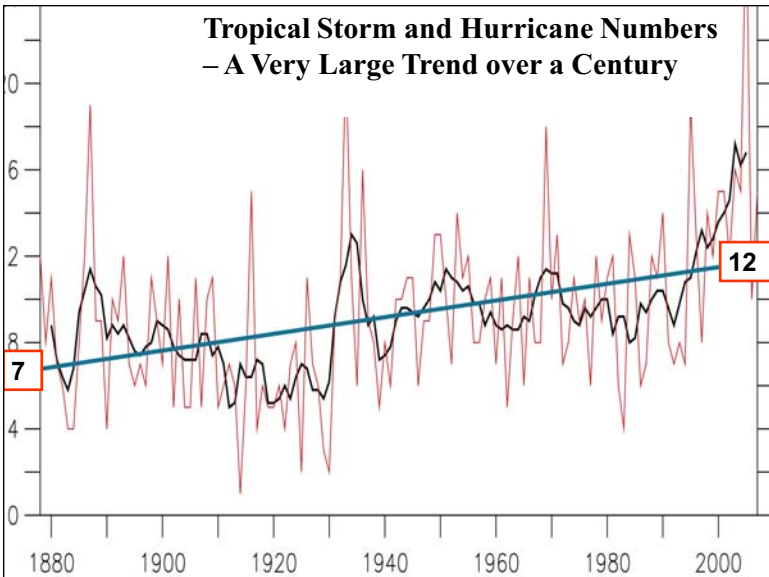
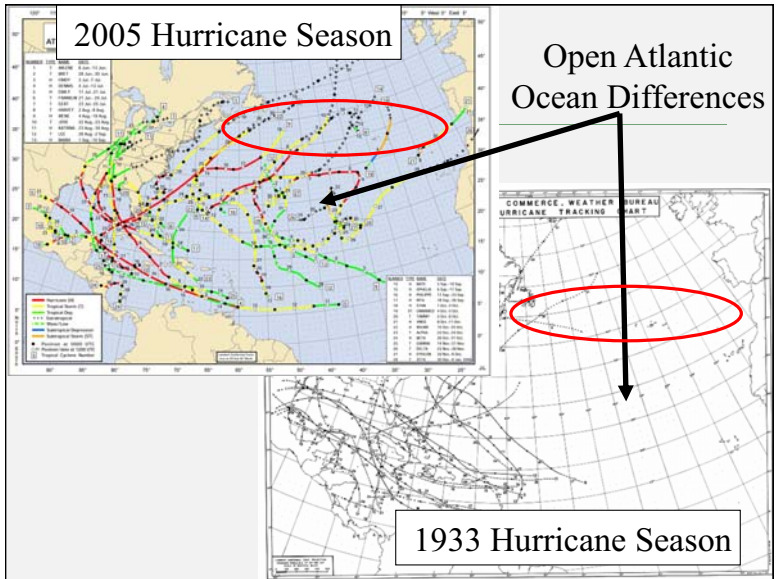


Atlantic Hurricane Database Re-Analysis Project

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

1851 through 1925 changes accepted and officially adopted by NHC. Revisions for 1926 to 1940 are currently being considered. Remainder of 20th Century currently being reanalyzed.

RE-ANALYSES NEED TO BE CONDUCTED GLOBALLY!!!

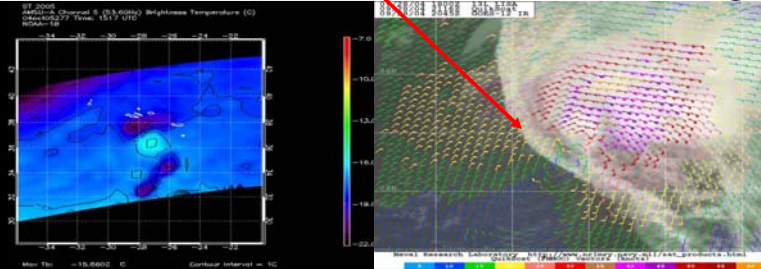


New Tools and Technologies ~ Additional TCs lately?

Hart's Cyclone Phase Space Analyses

Quikscat Surface Vectors

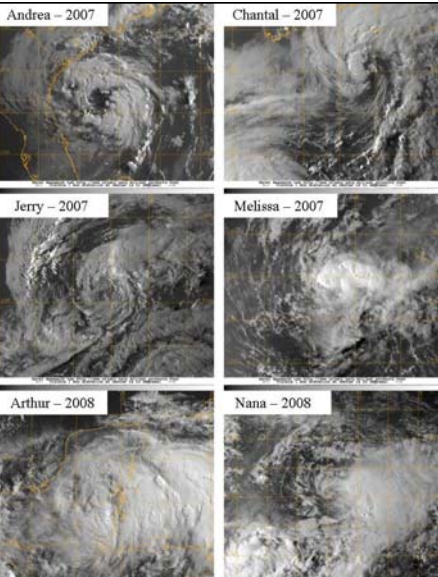
AMSU Tropospheric Temperatures



Changes in "Naming" Criteria

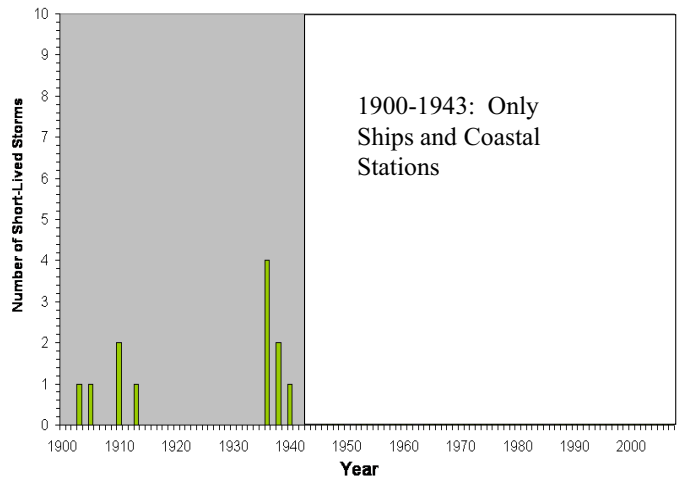
"If it was quite marginal as to whether or not a storm would be upgraded to tropical storm status or equivalent, that decision would likely be influenced by proximity to possible impacts on land within the next 48 hours or so. That is, I suspect that the margin of acceptable error for most of us would 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

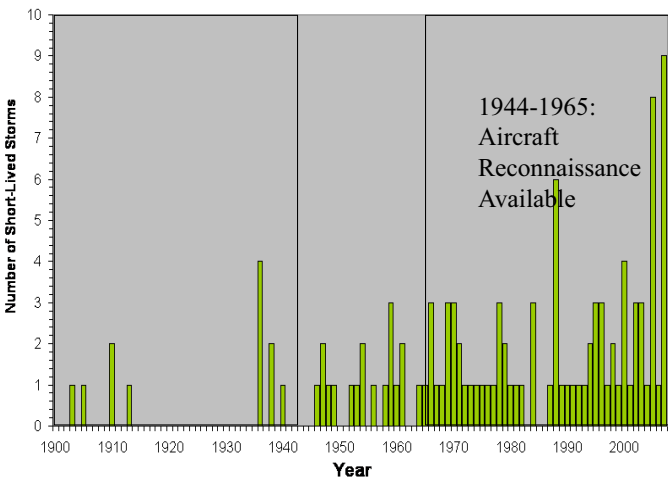


Six weak, short-lived storms in last two seasons
—
Unlikely to have been "named" previously

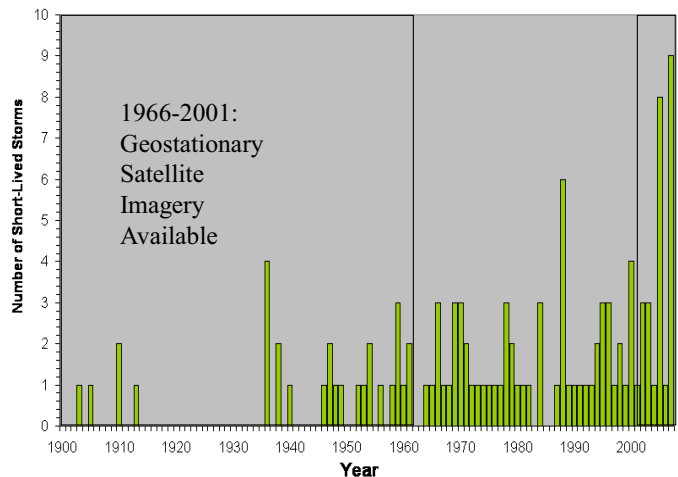
Short-Lived Atlantic Tropical Cyclones 1900-2007 1.5 Days or Less as Named Storm



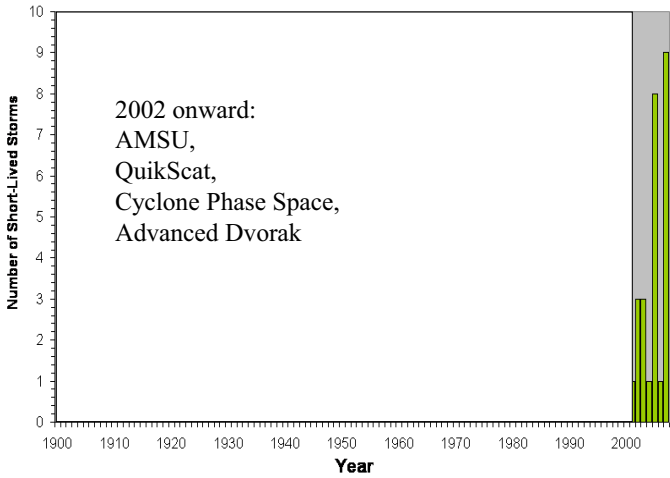
Short-Lived Atlantic Tropical Cyclones 1900-2007 1.5 Days or Less as Named Storm



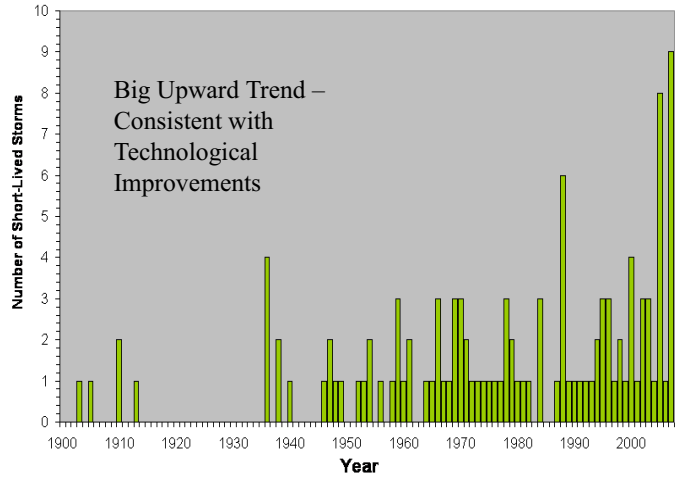
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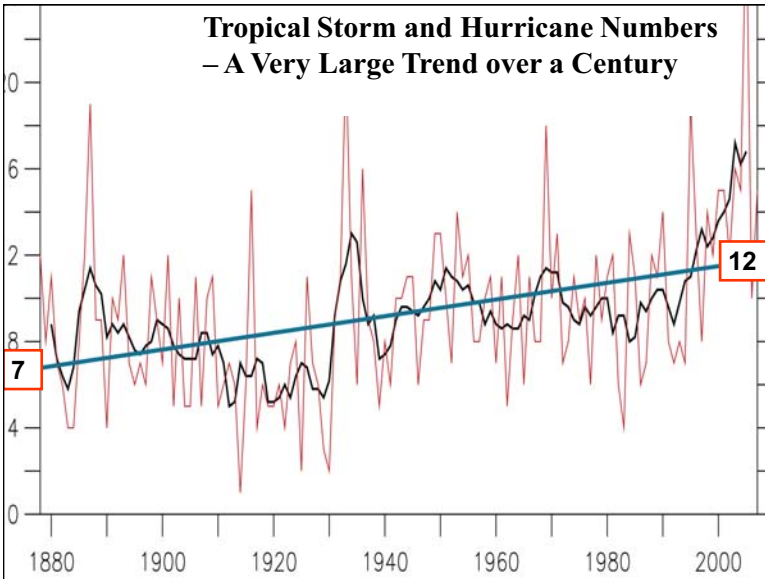
**Short-Lived Atlantic Tropical Cyclones
1900-2007 1.5 Days or Less as Named Storm**



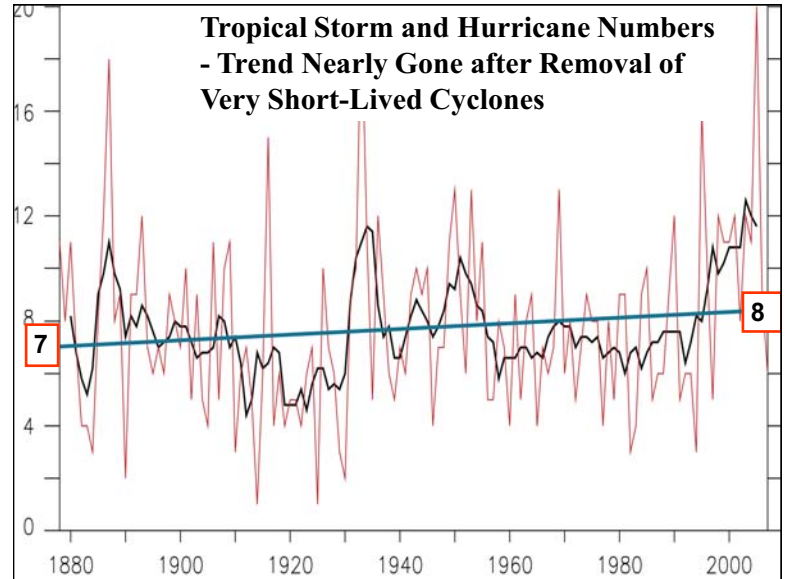
**Short-Lived Atlantic Tropical Cyclones
1900-2007 1.5 Days or Less as Named Storm**



**Tropical Storm and Hurricane Numbers
- A Very Large Trend over a Century**

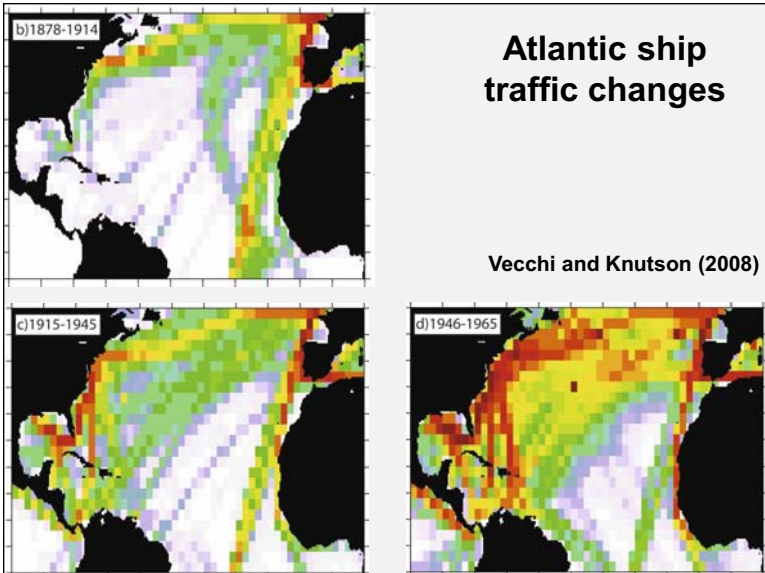


**Tropical Storm and Hurricane Numbers
- Trend Nearly Gone after Removal of
Very Short-Lived Cyclones**

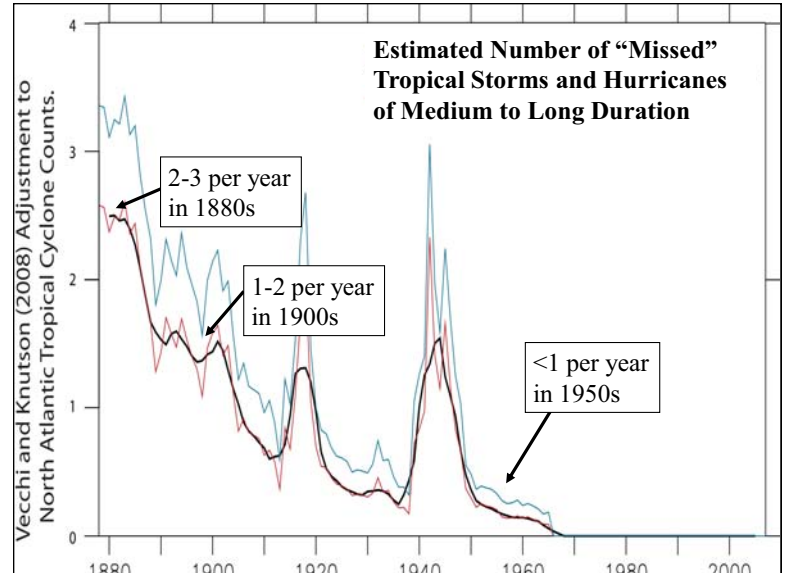


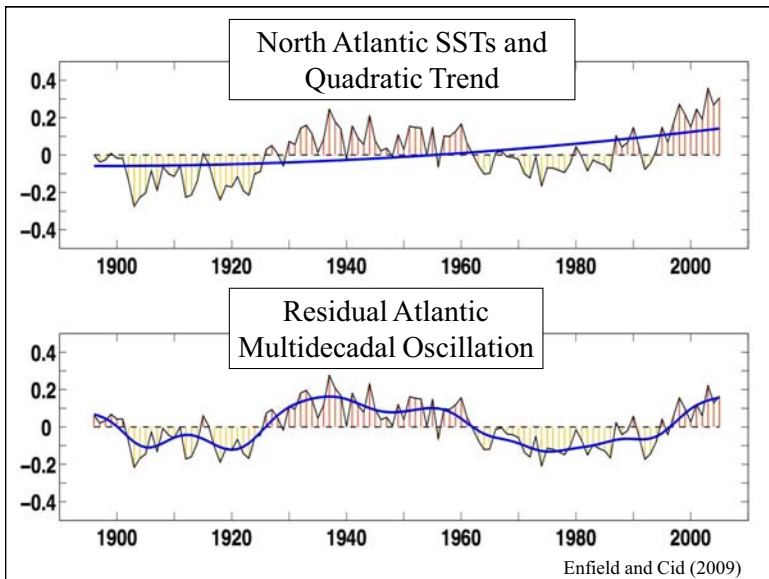
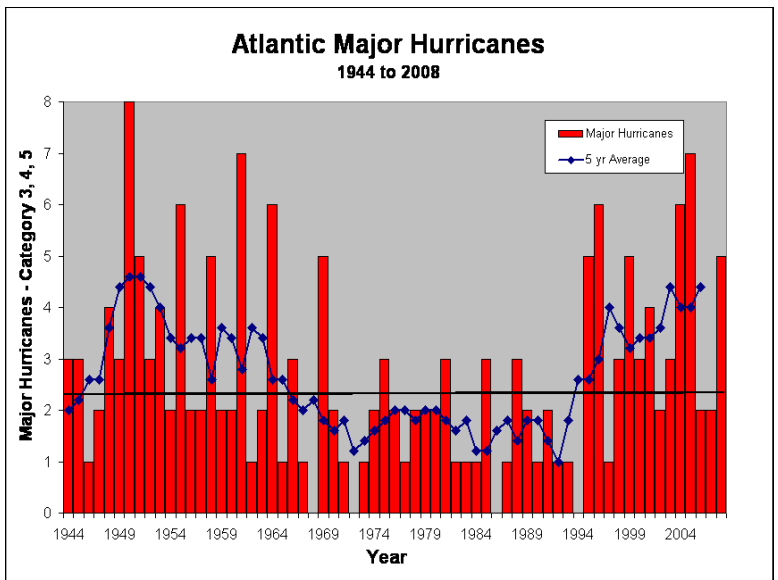
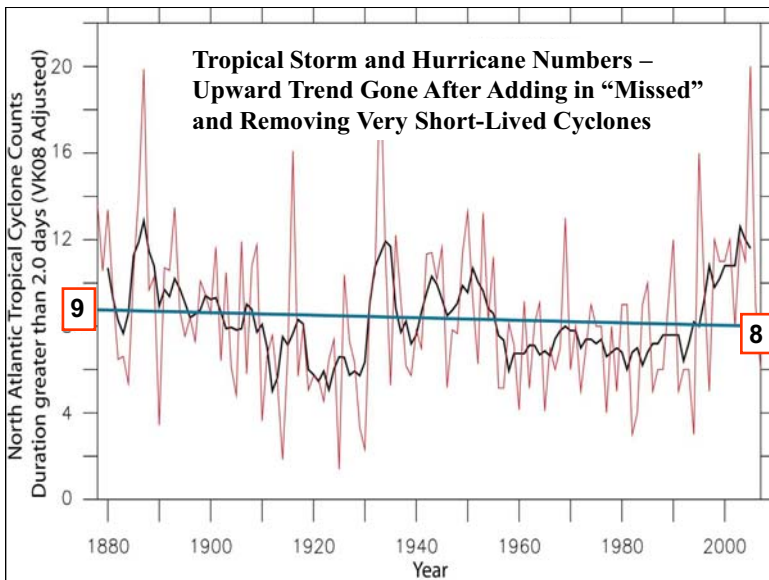
**Atlantic ship
traffic changes**

Vecchi and Knutson (2008)



**Estimated Number of "Missed"
Tropical Storms and Hurricanes
of Medium to Long Duration**





Overall Tropical Storm and Hurricane Changes Due to Global Warming by 2100

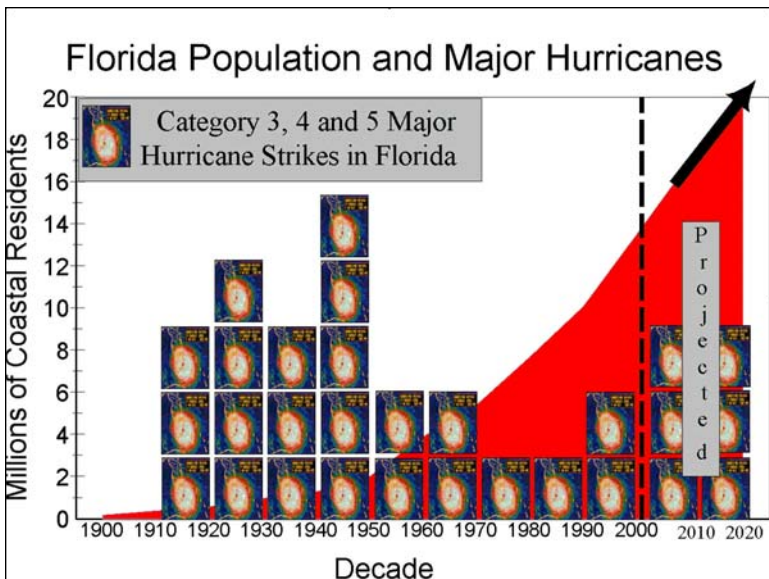
Numbers: Remain the same to a moderate decrease (~25%)

Wind Intensity: Small increase (~5% stronger)

Storm Surge: Small increase (~5% higher) produced by the hurricane (must also add on additional amount from general sea level rise)

Rainfall: Small increase (~10% within 200 mi of storm)

Genesis/Track: Not as certain, but no indications for large alterations



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Denise
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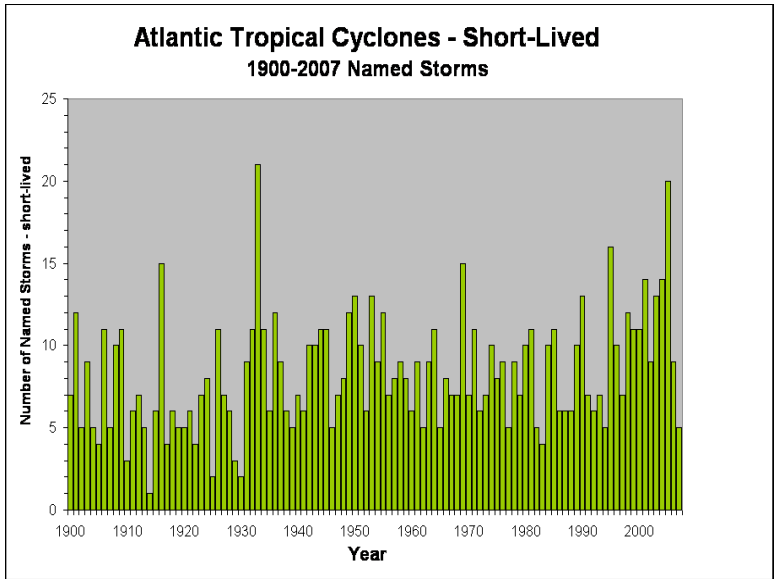
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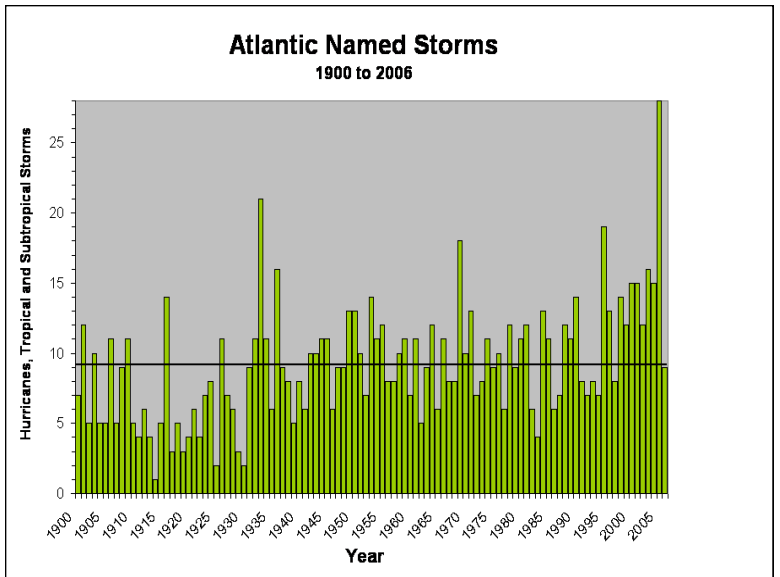
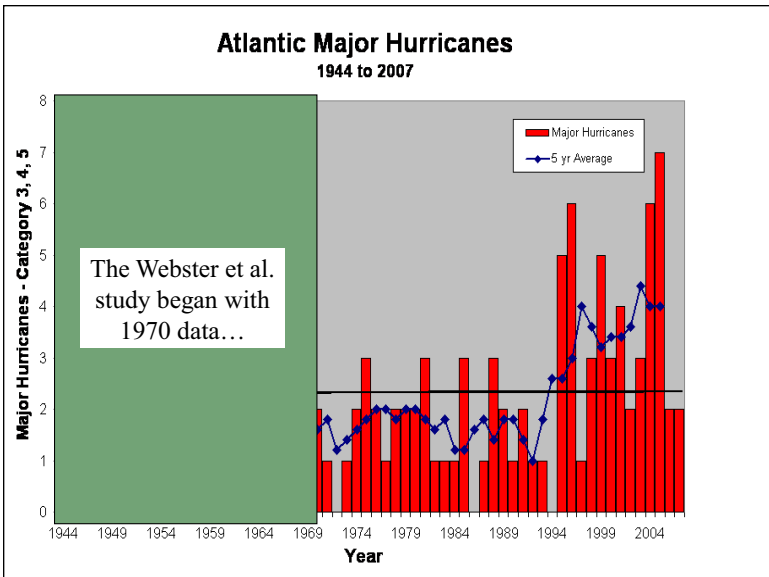
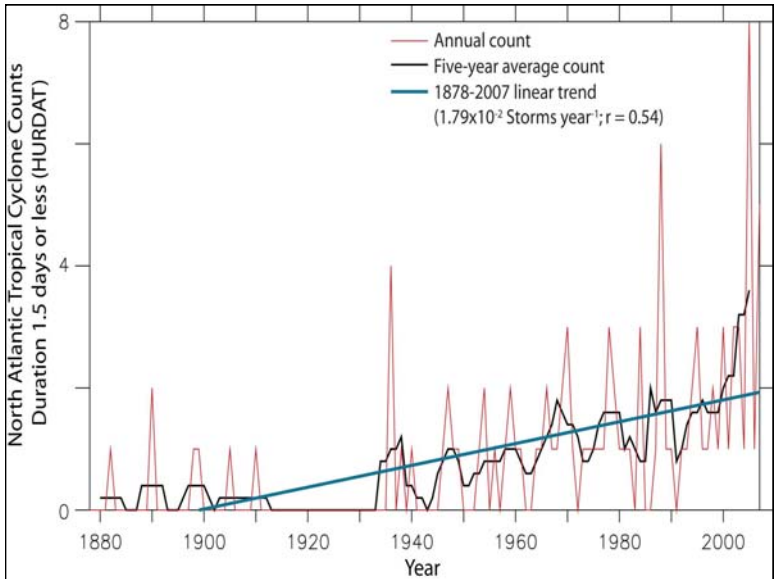
Wilma
21 October



Changes in "Naming" Criteria

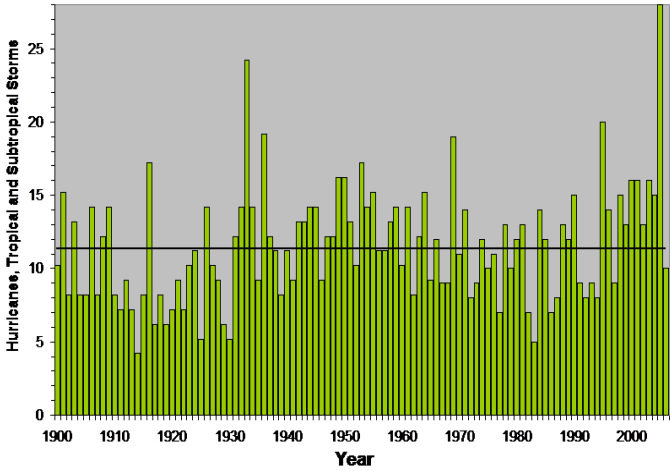
“ “[The National Hurricane Center] seems to be naming a lot more than they used to. This year, I would put four storms in the very questionable category, and maybe even six. In the past, we would have waited to see if another observation supported naming the system. We would have been a little more conservative.”

Neil Frank, National Hurricane Center Director, 1974-1987



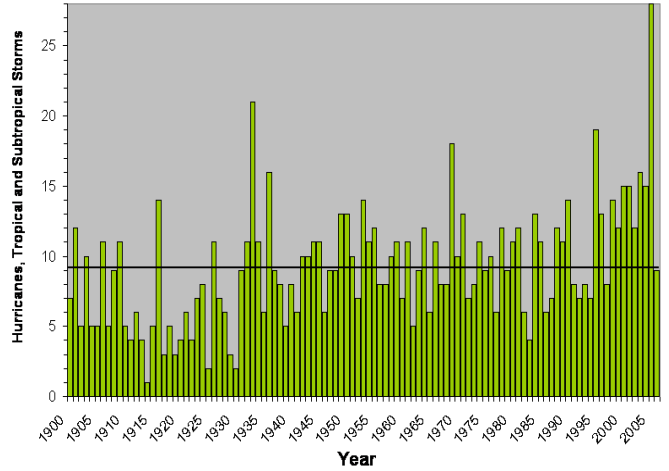
Adjusted Atlantic Named Storms

1900 to 2006 - Additional 3.2 for 1900-65, 1.0 for 1966-2002



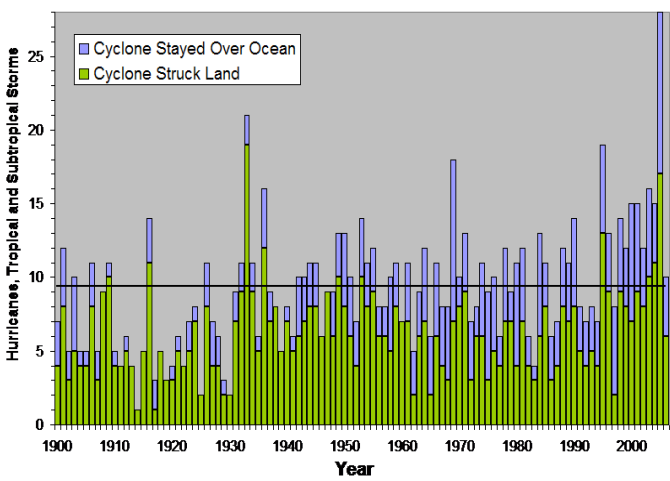
Atlantic Named Storms

1900 to 2006



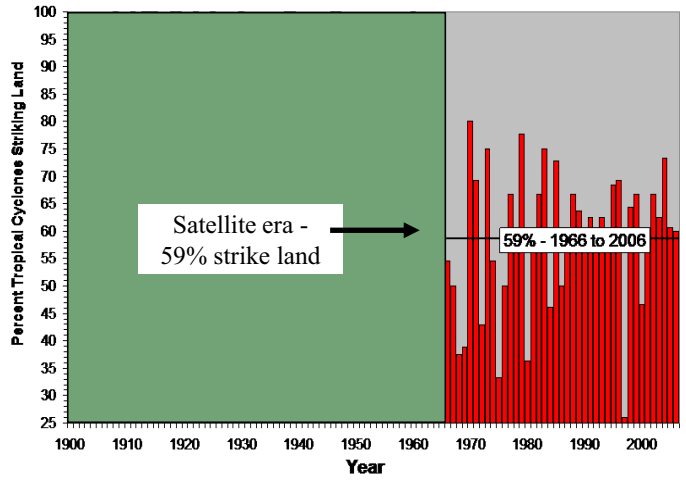
Atlantic Named Storms

1900 to 2006



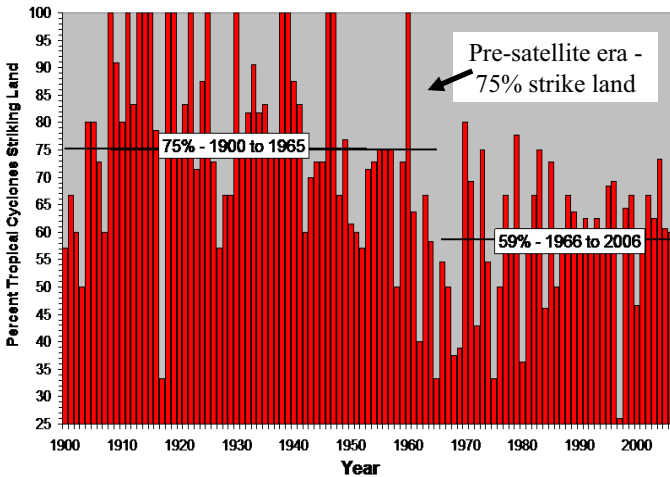
Percent Tropical Cyclones Striking Land

1900 to 2006

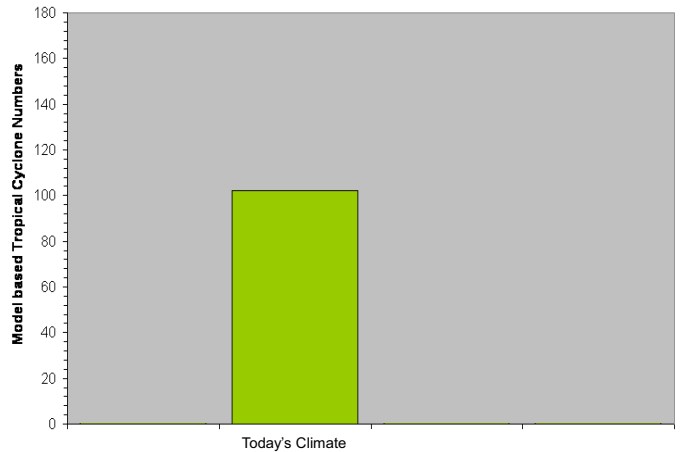


Percent Tropical Cyclones Striking Land

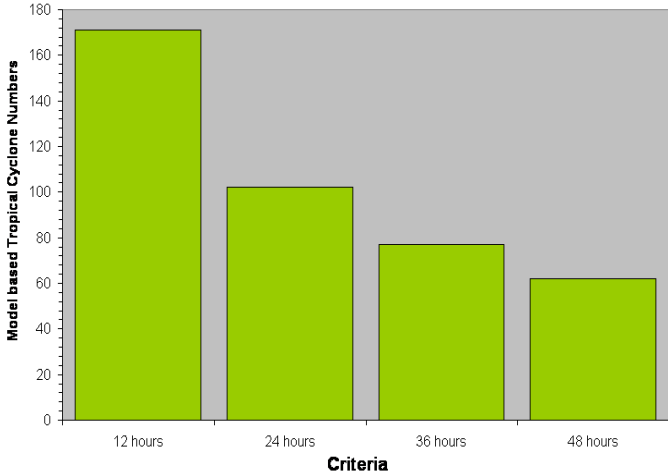
1900 to 2006



Frequency of Tropical Cyclones in Today's Climate



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



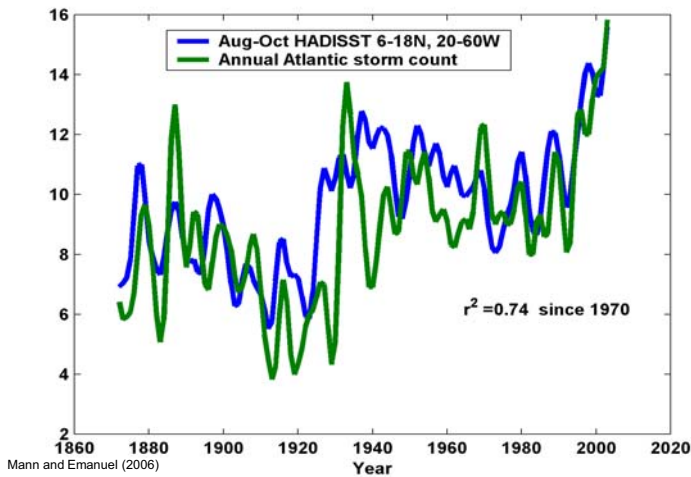
"This record [of Atlantic tropical cyclone counts] ... shows a strong, long-term relationship with tropical Atlantic August-October SST... The underlying factor appears to be the influence of (primarily anthropogenic) forced large-scale warming."

"Overall, there appears to have been a substantial 100-year trend leading to related increases of over 0.78C in SST and over 100% in tropical cyclone and hurricane numbers. It is concluded that the overall trend in SSTs, and tropical cyclone and hurricane numbers is substantially influenced by greenhouse warming."

EOS
 VOL. 31, NO. 12, 15 JUNE 2006
Atlantic Hurricane Trends Linked to Climate Change
 PAGES 233-243
 Increases in key measures of Atlantic hurricane activity over recent decades are believed to reflect, in large part, anthropogenic climate change. Using a formal statistical analysis to separate the estimated influences of anthropogenic climate change from possible natural cyclical influences, this article presents results indicating that anthropogenic factors are likely responsible for long-term trends in tropical Atlantic weather and tropical cyclone activity.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY
 FirstCite e-publishing
 Phil. Trans. R. Soc. A doi:10.1098/rsta.2007.2083 Published online
Heightened tropical cyclone activity in the North Atlantic: natural variability or climate trend?
 BY GREG J. HOLLAND¹ AND PETER J. WEBSTER^{2*}

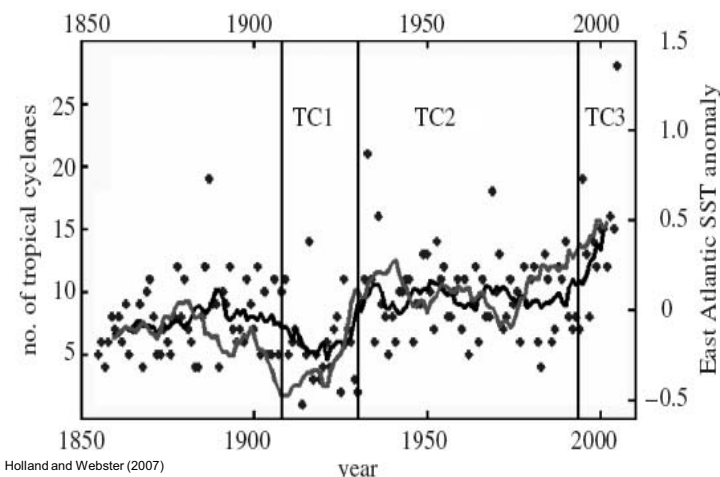
Linking frequency of Atlantic tropical cyclones to SSTs



"Although wind estimates prior to the 1940s are problematic, detection of the existence of tropical cyclones is less so, because without aircraft and satellites to warn them off, ships often encountered storms at sea, at least peripherally. A reasonably reliable record of annual North Atlantic tropical cyclone counts is thus available back into the late nineteenth century."

--- Mann and Emanuel (2006)

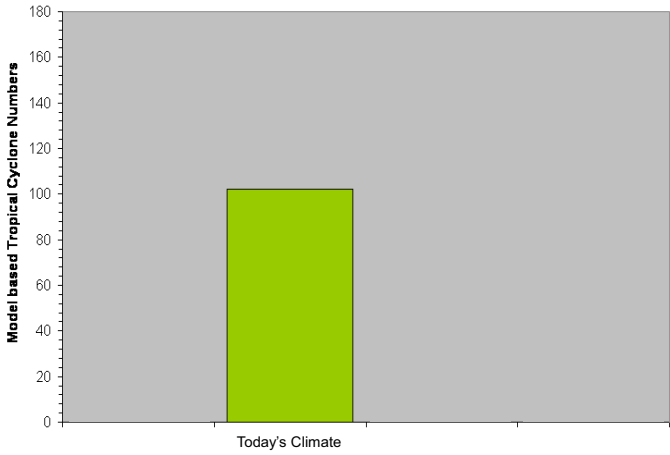
Linking frequency of Atlantic tropical cyclones to SSTs



"Questions have been raised over the quality of the NATL data even for such a broad brush accounting. We have carefully examined the data record and considered as yet unpublished analyses by other investigators. Our conclusion is that the number of earlier missed storms most likely lies between 1 and 3 per year prior to 1900, less than 2 in the early nineteenth century [sic] and dropping off to essentially zero by 1960."

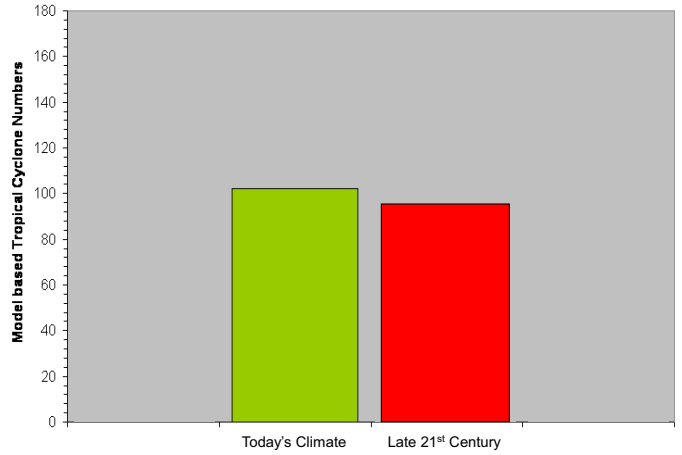
--- Holland and Webster (2007)

Frequency of Tropical Cyclones in Today's Climate

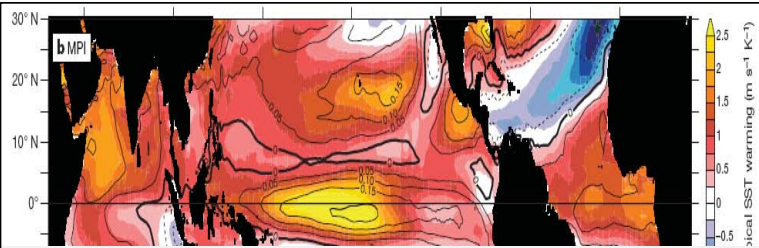


Bengtsson et al. (2007)

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



Bengtsson et al. (2007)



Maximum Potential Intensity Change
 Atlantic Basin: +2% stronger per °F SST change
 Vecchi and Soden (2007)

Normalized Atmospheric Temperature Change

