

Tropical Cyclone Activity in the Caribbean: Is it Increasing?

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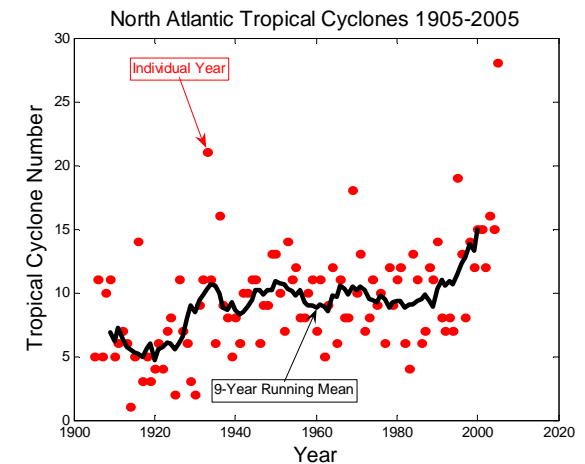
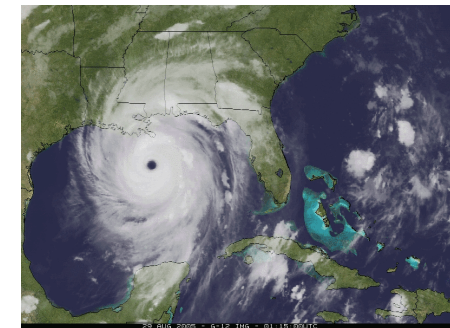
Summary:

Summary of Past Hurricane Activity

Issues on Data Reliability

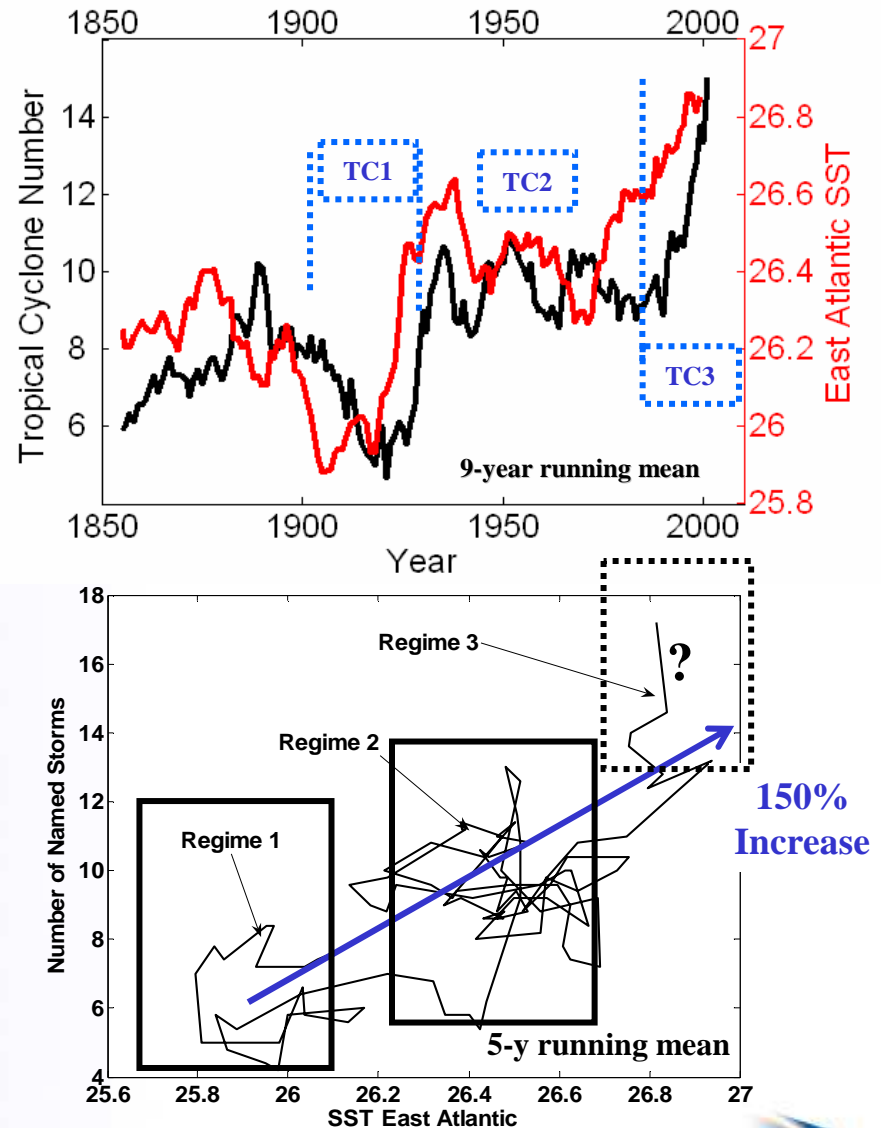
Attribution of Changes

The Future



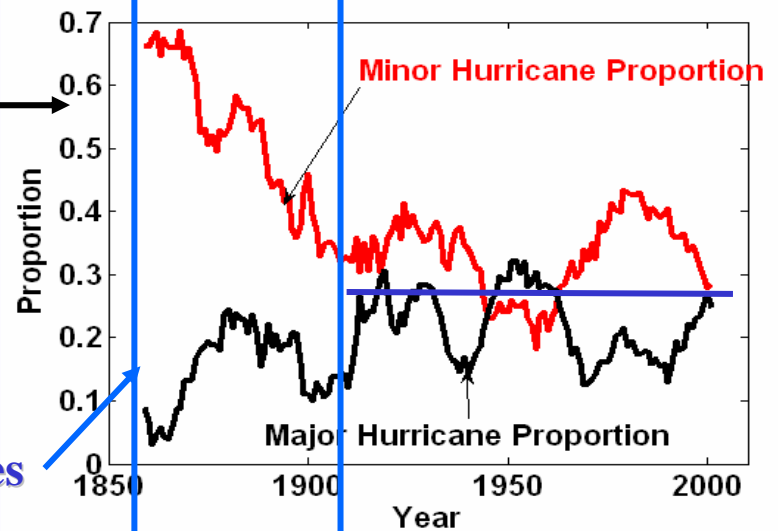
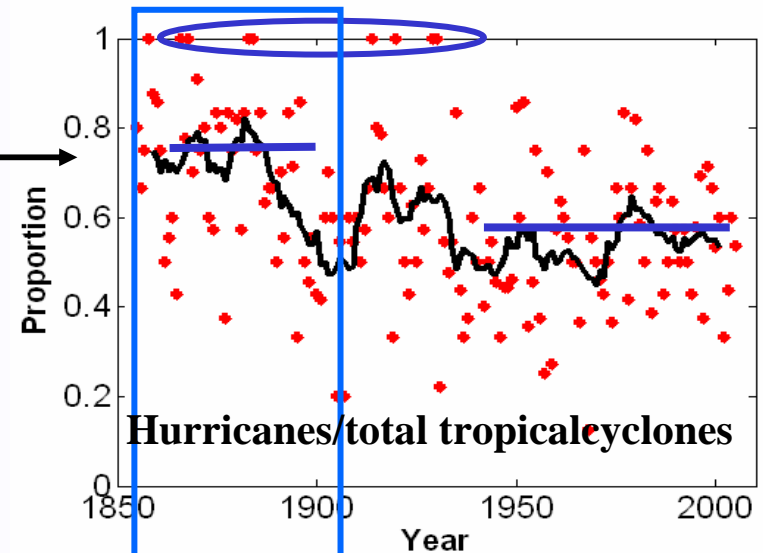
Summary of Past Activity

- A marked increasing trend in tropical cyclone frequency closely associated with increasing eastern North Atlantic Sea-Surface Temperatures (SSTs, e.g. Holland and Webster 2007);
- *We emphasize that the SST-TC relationship is not entirely direct, but arises from related atmospheric environmental changes e.g., vertical wind shear (e.g. Goldenberg et al 2001; Delworth 2006; Kossin and Vimont 2007), stretching deformation (Webster and Holland 2007).*



Proportion of major/minor hurricanes

- Stable proportions of hurricanes to all tropical cyclones over the past 50-100 years (the higher earlier proportions are considered due to analysis errors);
- Stable major/minor hurricane proportions but with a marked, multi-decadal oscillation (peaks associated with equatorial developments and expansion of the warm pool);
- Thus, the numbers of hurricanes and major hurricanes has increased in line with that for all tropical cyclones.

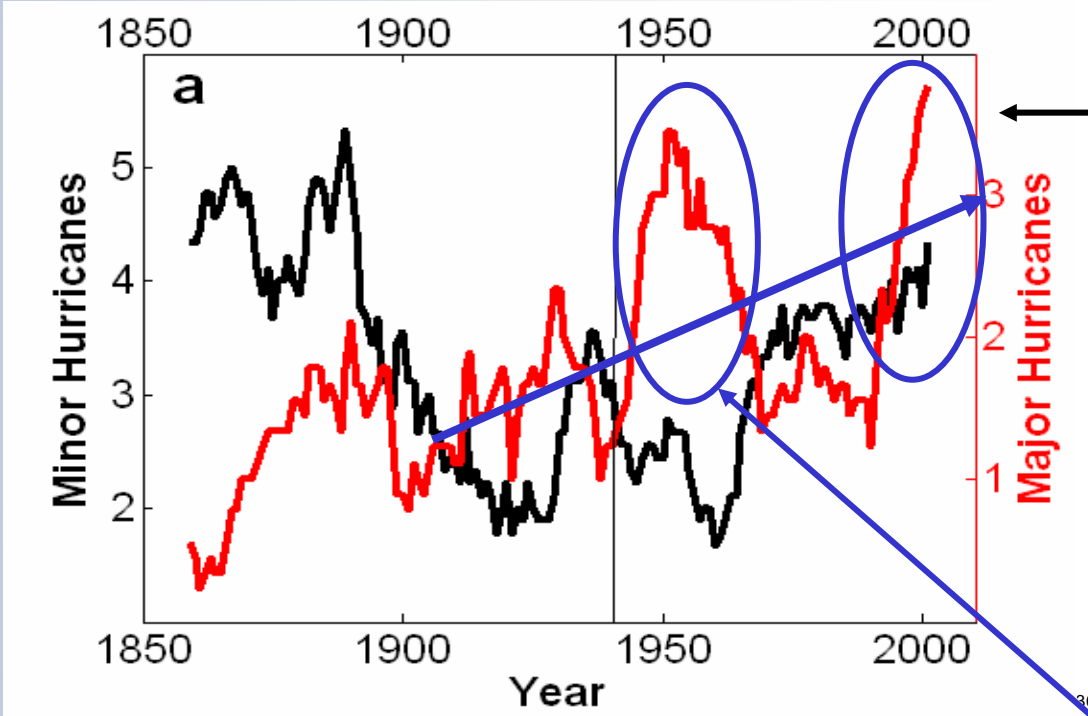


Holland-Webster (2007)



Data Issues

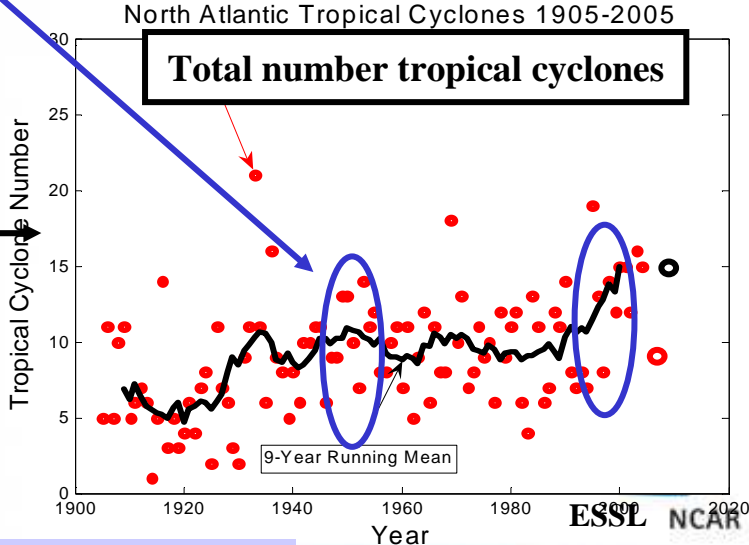
Ratio of major to minor hurricanes



Combining the oscillation in major hurricane proportions with increasing cyclone numbers, leads to a substantial increase in total numbers of tropical cyclones;

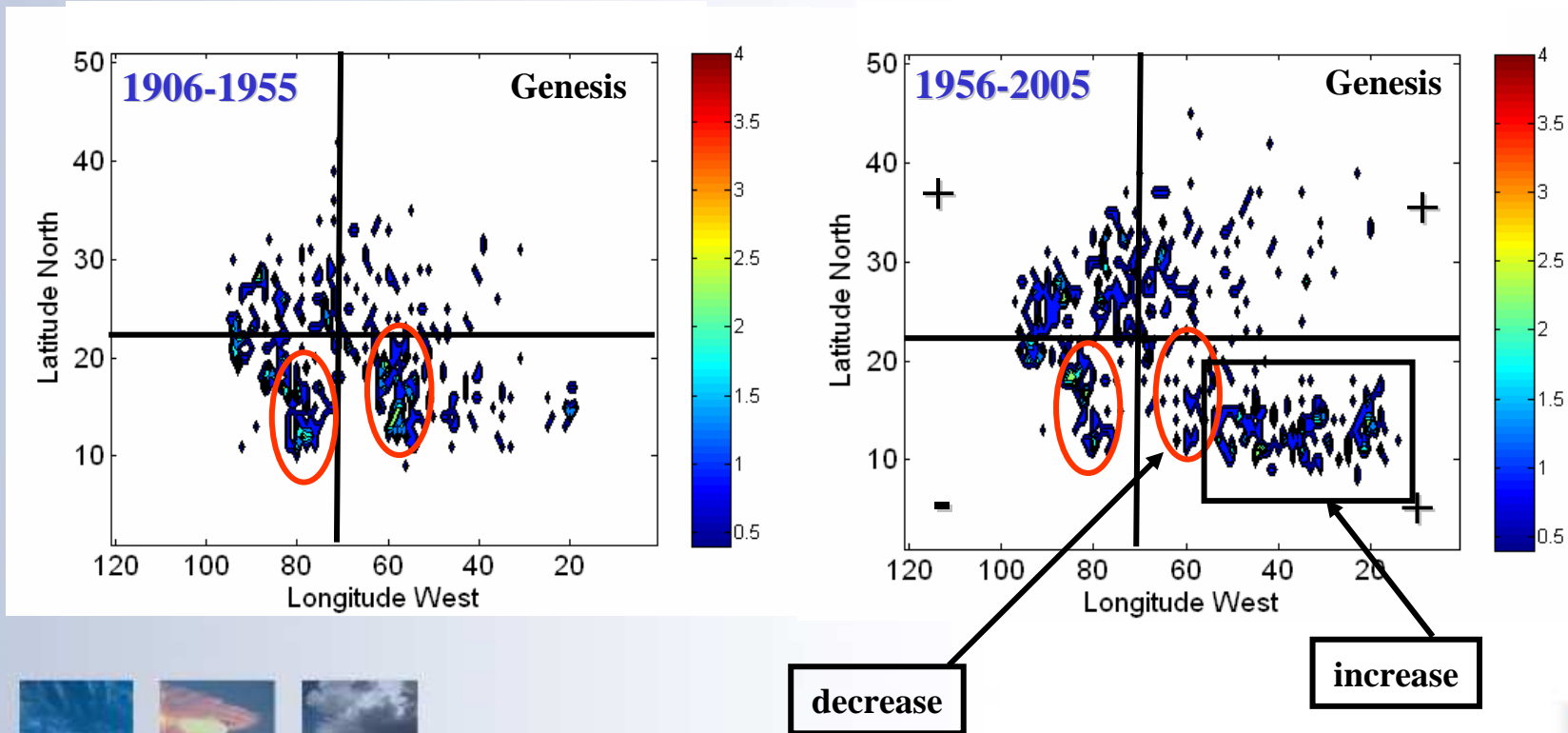
This increase is especially apparent in the Caribbean region.

Note that the previous “active” period in the North Atlantic (1950-1960’s) was due mainly to an oscillation in major hurricane proportion.



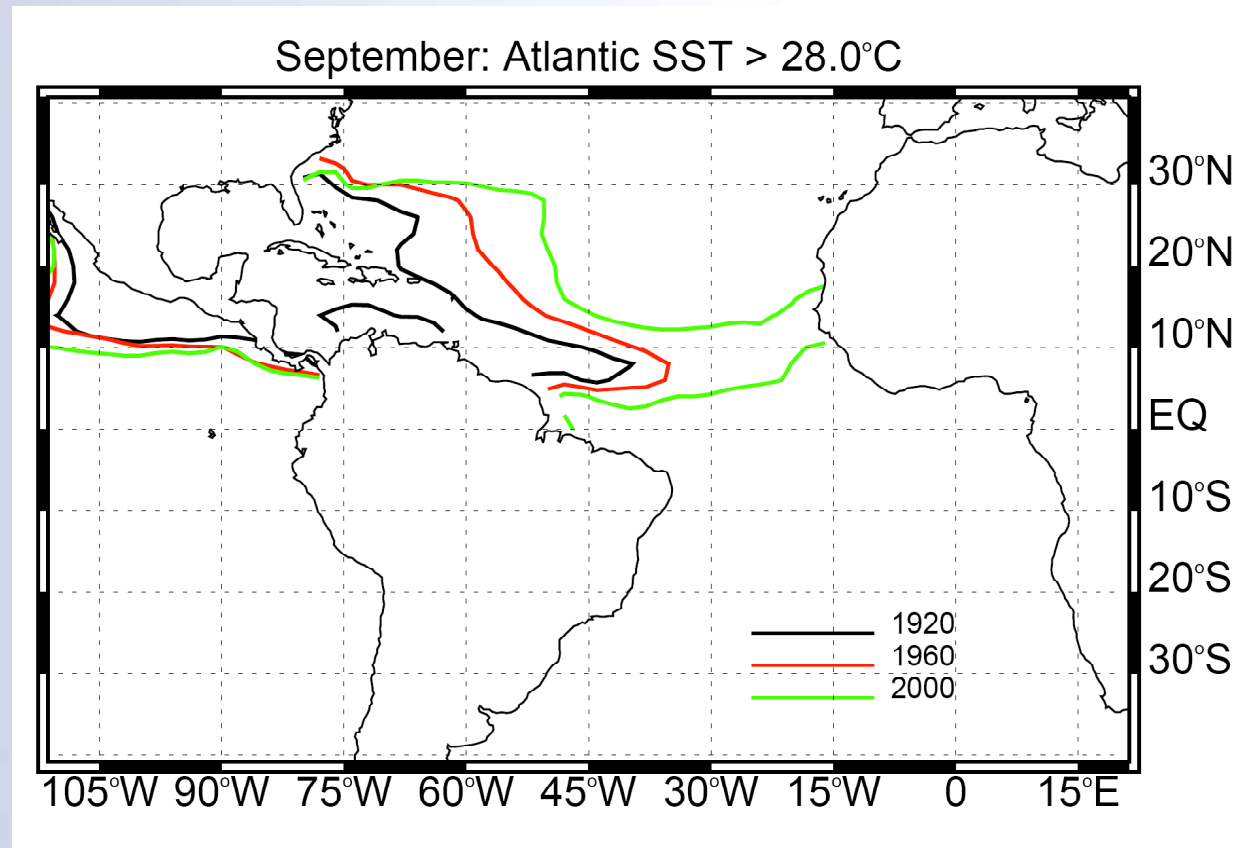
Where have the Increases Occurred?

- Increases have been mainly in eastern tropical regions (the infamous Cape Verde Storms);
- Western Caribbean and southern Gulf of Mexico have decreased (associated directly with more developments east of the Windies);
- Eastward expansion is partly due to data issues (picking up genesis as storms moved over the Windward Islands), and partly real



Why is there an Eastward Expansion?

- Increases are consistent with the expansion of the North Atlantic Warm Pool.



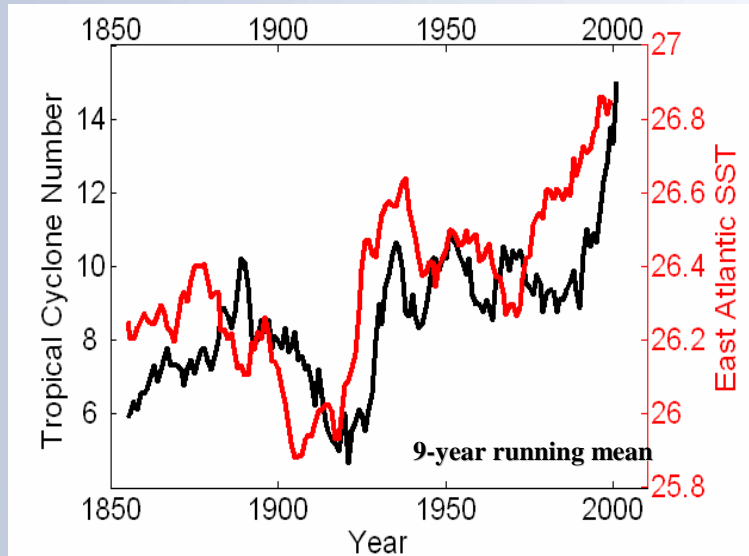
Webster and Hoyos (2007)



Attribution of Changes



Attribution from assessments



SST has same characteristic variability as cyclone numbers and explains >60% of tropical cyclone variability

(Curry talk)



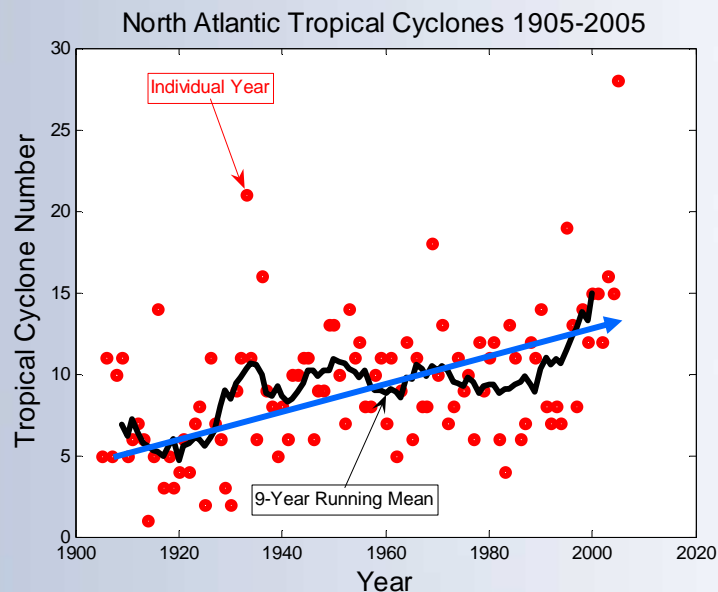
- **WMO IWTC-VI:**

- **Though there is evidence both for and against the existence of a detectable anthropogenic signal in the tropical cyclone climate record to date, no firm conclusion can be made on this point.**

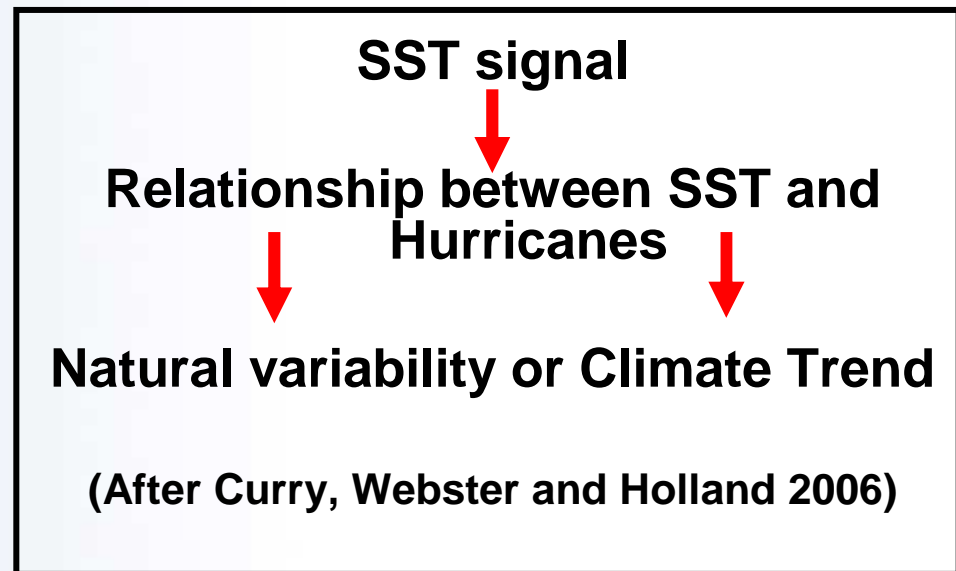
- **IPCC:**

- **Likely that increases have occurred in some regions since 1970 esp NATL;**
- **More likely than not a human contribution to the observed trend;**
- **Likely that there will be future increases in tropical cyclone intensity and heavy precipitation associated with ongoing increases of tropical SSTs.**

Natural Variability vs Climate Trend?



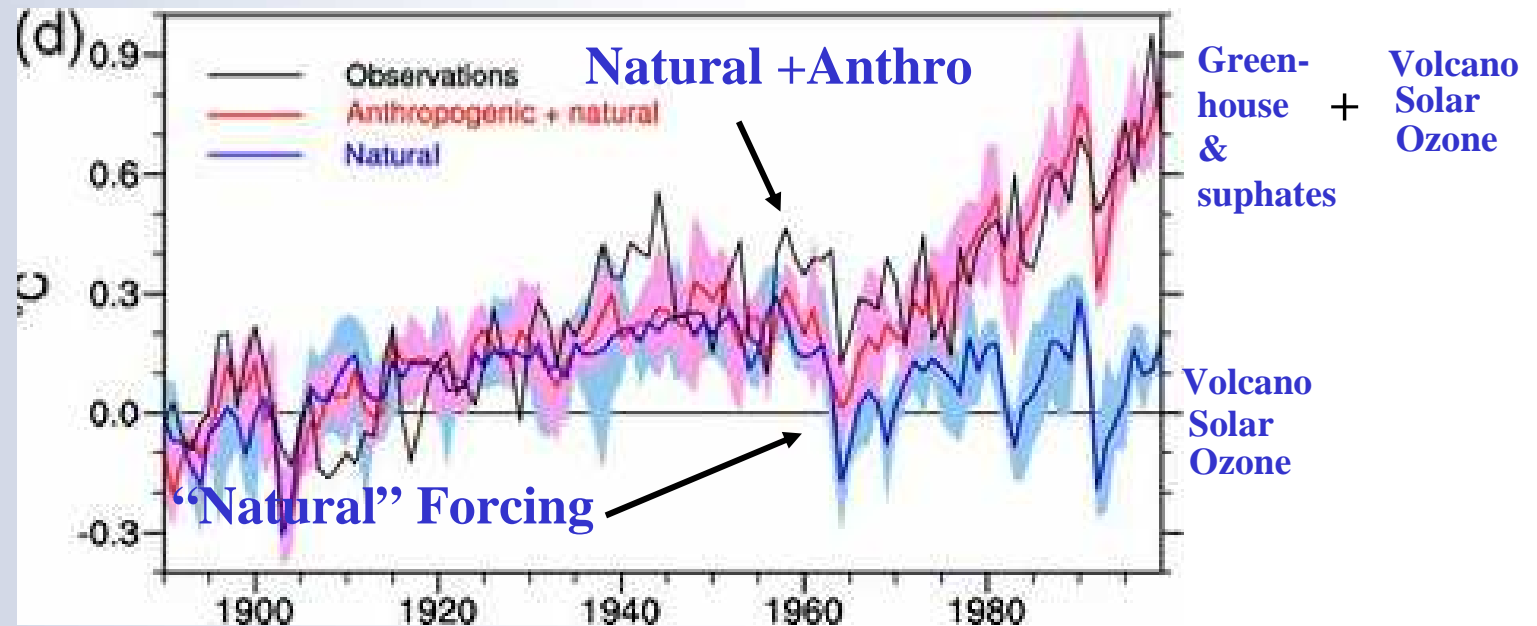
We address the causal relationship:



These arguments have been discussed in detail in the Curry presentation



Global Surface Temperature Variability

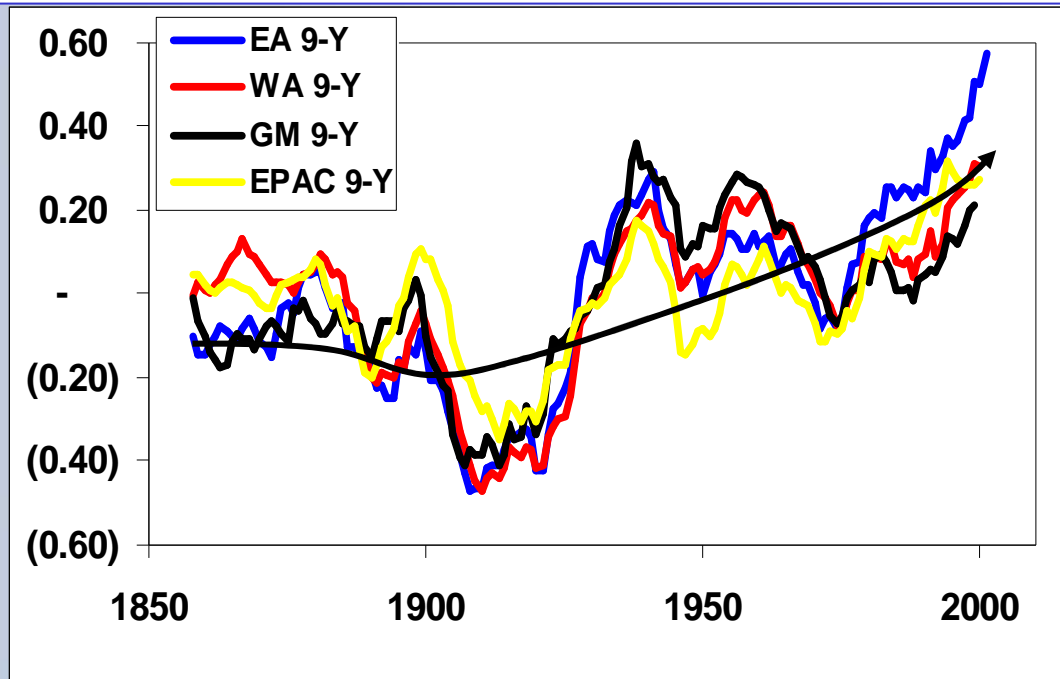


There is no known natural forcing mechanism that can explain the surface temperature increases since 1960 (Meehl et al 2004, 2006).

IPCC concluded that it is very likely (>90%) that most of the the SST increases are due to anthropogenic causes.



Natural cycles versus anthropogenic influences



EA= Eastern North Atlantic; WA=Western North Atlantic; GM=Gulf of Mexico; EPAC=Eastern North Pacific.

Note SST increase largest in Eastern ATL

Atlantic Multidecadal Oscillation?

Various claims of a relationship (Bell and Chelliah 2005, Goldenberg et al 2001)

BUT

Mann and Emanuel (2006), Trenberth and Shea (2005), Bryden et al (2005), Santer et al. (2006) and others disagree.

Conclusion: A small contribution by NAO-AMO, but major contribution is anthropogenic.



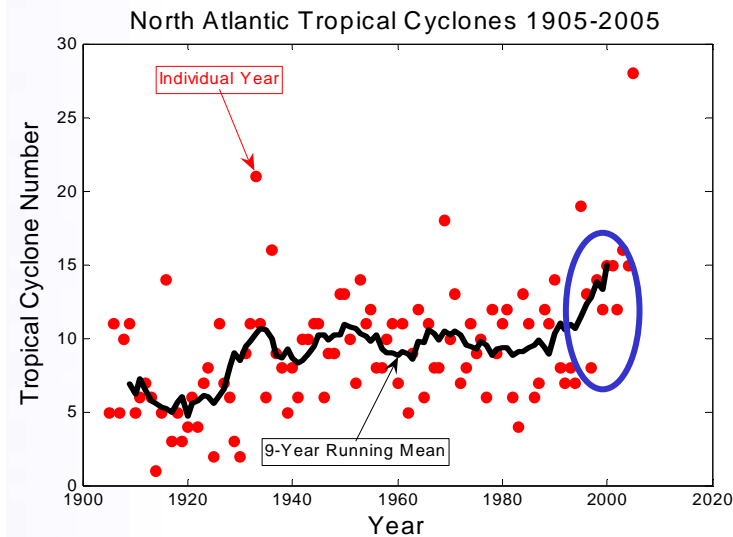
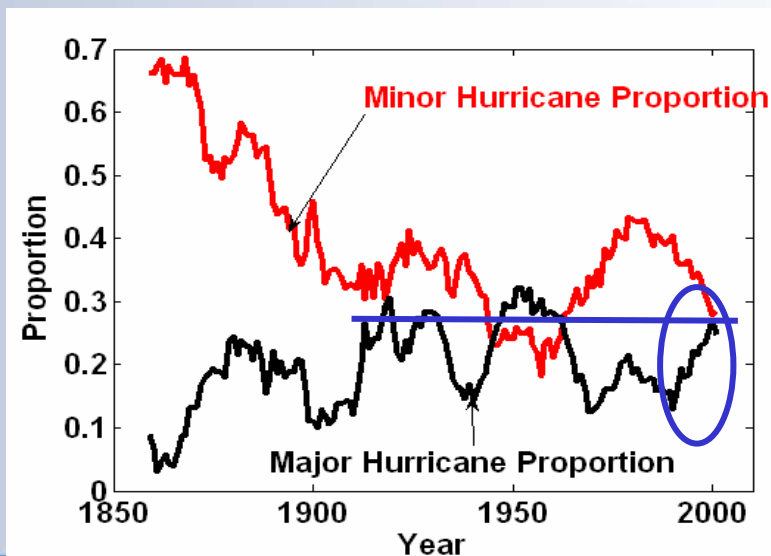
SST-Hurricane Relationship

- Webster et al (2005), Emanuel (2005) and Hoyas et al (2006) noted a strong global relationship with climatological intensity changes.
- Gray (1990), Landsea et al (1999), Goldenberg et al (2001), Vitart and Anderson (2001) all find a strong relationship between eastern North Atlantic SSTs and tropical cyclones.
- We have shown that Eastern North Atlantic SSTs explain >60% of smoothed variance in Atlantic Tropical Cyclones since 1905, due entirely to regime changes associated with anthropogenic warming;
- ***We again emphasize that the SST-TC relationship is not direct, but arises from related atmospheric environmental changes, such as vertical wind shear, stretching deformation, vertical stability.....***



Historical Changes Conclusion

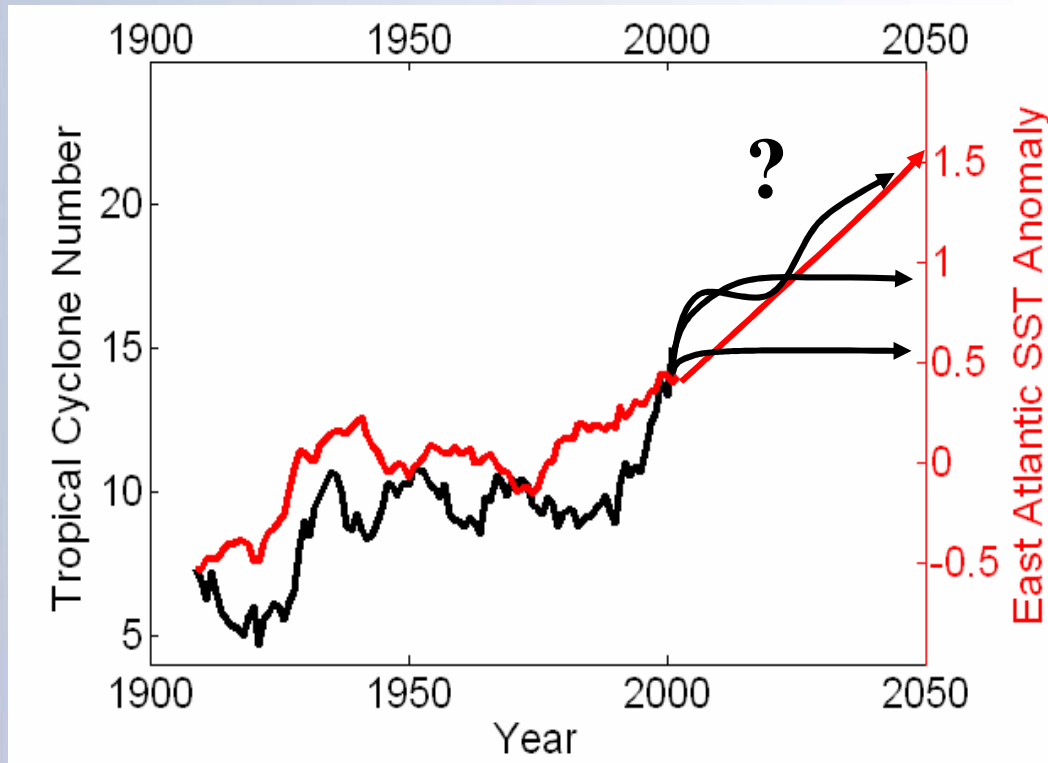
- North Atlantic tropical cyclone frequency changes due to anthropogenic climate change are not in the future, a significant trend appears to have already occurred.
- This is consistent with the climate change modeling studies by Oochi et al (2006), Bengtsson et al 2007, and recent unpublished modeling work by Knutson et al.
- There is in addition a substantial multi-decadal oscillation in proportions of major and minor hurricanes.



Both Proportion and Total Number are Currently Increasing

“The future comes apace”

Shakespeare

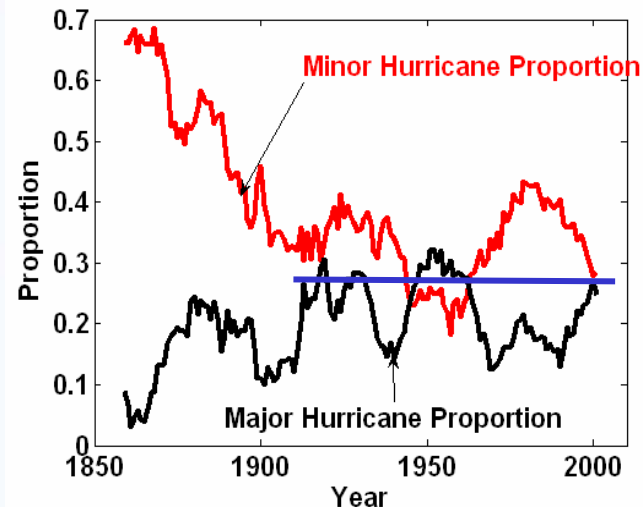
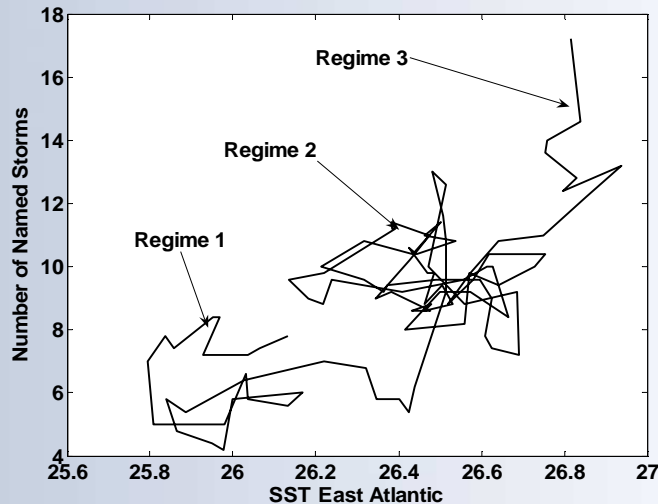


- **5-10Year Outlook**
- **1-2-Year Variability**
- **20-30-Year Outlook**



5-10 year Activity Outlook

- Virtually certain that the current high level of activity will remain at current or higher levels;

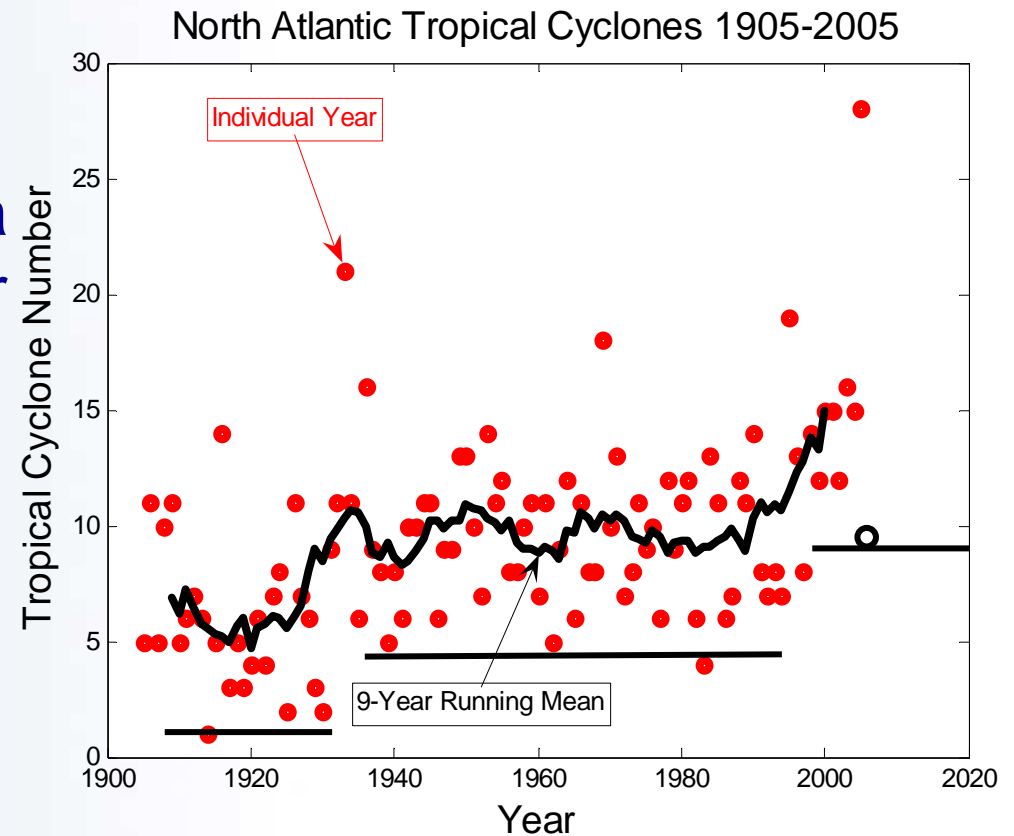


Note that:

- The current upward surge in cyclone numbers has not yet stabilized, running at 14 per year on average since 1995;
- AMO contribution will result in an increase until 2020 or thereabouts;
- Simple historical extrapolation (due to SST warming trends) indicates that the proportion of major hurricanes will continue higher.
- Great uncertainty regarding magnitude of trends/natural variability: Physical understanding of changes greatly challenged.

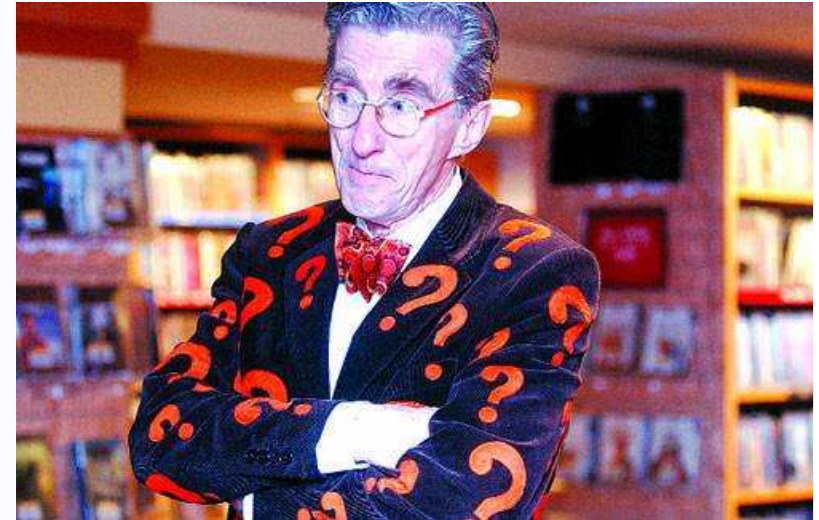
1-2 Year Variability

- Dominated by El Nino-La Nina;
- Most likely that minima will be similar to means for the 1980s;
- Maxima will be above 20 with increased frequency and could exceed 30.



30-50 Year Outlook

- **Must rely on climate models;**
- **Considerable uncertainty;**
- **Oochi et al 2006:**
 - *Increase in numbers in North Atlantic, decrease elsewhere;*
 - *Small increase in intensity globally;*
- **Bengtsson et al 2007:**
 - *Stable or slightly increased numbers in North Atlantic and eastern North Pacific, decrease elsewhere;*
 - *General small increase in intensity, but 30% increase in major hurricanes in North Atlantic by 21st century.*



Other Factors

- It is too late for preventive emission actions to have an effect for decades yet;
- **Sea Level Rise will substantially amplify impacts;**
- **Overland Damage from Flooding, Tornadoes and Local Wind Bursts;**
- **Demographic and Commercial Activity Changes:**
 - *In some quarters sold as implying no real importance of changes in hurricane characteristics (Pielke et al), whereas it really means the meteorological and oceanic changes become more important (e.g. Anthes et al 2007).*
 - *I.e., Societal consequences of small changes are amplified*



Summary

- There is a substantial trend in North Atlantic tropical cyclones and hurricanes and both a multidecadal oscillation and trend in major hurricanes;
- The trend is strongly related to Atlantic SST and thus probably can be attributed to both long-period oscillations, such as the North Atlantic Oscillation (NAO) and Greenhouse Warming, with GW being the dominant factor;
- It is most likely that current elevated activity in the North Atlantic will continue for at least the next 5-10 years and will include a high proportion of major hurricanes;



Summary

- There will be a substantial interannual variability with minima around 8-10 and maxima exceeding 20;
- Multi-decadal trends are more difficult to assess: unlikely that there will be a decrease: current models show increasing numbers and increasing intensity for the North Atlantic;
- Landfall impacts on US coastal regions are difficult to assess: again unlikely that there will be a decrease in the next 5-10 years and increased frequency of major hurricane impacts is more likely than not.
- Ditto Caribbean region



Major References Used

- Holland, G.J. and P.J. Webster, 2007: Heightened tropical cyclone activity in the North Atlantic: Natural variability or climate trend? *Phil. Trans. R. Soc. A*, (In press).
www.mmm.ucar.edu/people/holland/files/NaturalVariabilityOrClimateTrend.pdf
- Curry, J., 2007: Statement to the Select Committee on Energy Independence and Global Warming of the United States House of Representatives Hearing on “Dangerous Climate Change” 26 April 2007.
- Curry, J. A., Webster, P.J., Holland, G. J., 2006: “Mixing politics and science: Testing the hypothesis that greenhouse warming is causing a global increase in hurricane intensity. *Bull. Amer. Meteor. Soc.* August 2006, 87 (8), 1025-1037.
- Webster, P.J. and C. Hoyos, 2007: The expanding tropical warm pool and associated changes in circulation. To be submitted to *Nature*.

