Institute and Faculty of Actuaries

Interpreting the Climate Record for Trends in North Atlantic Hurricanes

Dr Tom Philp

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Catlin Group Limited

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Presentation Roadmap

- 1) Hurricanes and their Historical Impacts on Society
- 2) Atlantic Hurricanes: Formation and Forecasting/Prediction
- 3) Atlantic Hurricanes and Climate Change: The Science
- 4) Where do Atlantic Hurricane Records Come From?
- 5) An Investigation of HURDAT
- 6) Historical Hurricanes: Lessons Learned?
- 7) Atlantic Hurricanes and Historical Losses

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Hurricanes:
A Historical Introduction

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Atlantic Hurricanes and Society

- Cause billions of dollars of damage each year.
- The 5 most destructive Atlantic hurricanes of the past 10 years (not including Sandy) have caused a combined loss of ~$190billion.

Match the GDP of the Czech Republic


Match NASA's spending on the entire 40 year history of its space shuttle fleet


Have the lion's share of a deposit for a 2-bed ex-council flat in London

- Devastating loss of life – Hurricane Mitch in 1998 caused the deaths of 11,000 people in Central America, the Yucatán Peninsula & South Florida
- In recent years, an obsession with weather and climate trends has developed, with particular emphasis on anthropogenic change.

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Kamikaze

- Kublai Khan – 1274 – launched a 40,000 man strong naval invasion of Japan at the height of the Mongol Empire.
- A typhoon drowned 13,000 of the force, wrecking many of the ships. The invading forces returned.
- After China fell to him in 1279, Kublai Khan once again re-focused on claiming Japan for the Mongol Empire.
- In 1281 sent a force of 140,000 men to take the island.
- The magnitude of this Naval invasion has only been surpassed once in history – during the D-day landings.
- The Japanese, now better prepared, held them at the coast for six weeks – and history repeated itself.
- Again, most of the invading force was drowned, and the fleet wrecked.
- The Japanese came to think of Typhoons as "Kamikaze"
  - = Spirit/Divine Wind.

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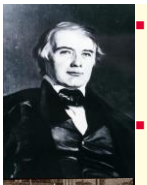
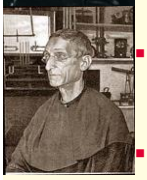
The Building Blocks: Pre-1900





- James Pollard Espy: 1840 – theorised that storms resulted from surface heating, air rising, and subsequent condensation.
- Elias Loomis & William Reid, 1830s &1840s: from damage, hypothesised that air in a storm spirals towards its centre.
- Benito Viñes disproved the common misconception that hurricanes and intense storms only rise ~1km, and was also the first to issue hurricane forecasts, in 1875.
- The forecasts were accurate & were considered “supernatural”.
- However, the lack of meteorological centres in the tropics meant that the study of Tropical Cyclones lagged behind that of mid-latitude storms.
- It wasn’t until aircraft reconnaissance during WWII that understanding of Tropical Cyclones really began to advance…

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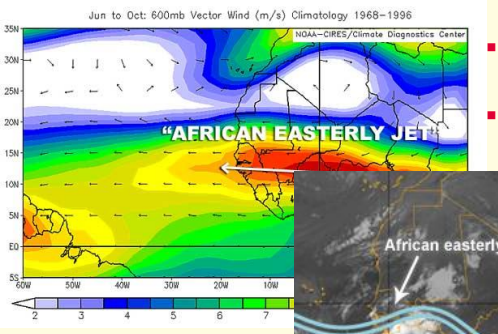
World War II and the Hurricane Hunters

- Taunted by British pilots about his lack of combat experience, US Air Force Col. Joseph B. Duckworth probably didn’t fully appreciate what, to you and me, is identifiable as the building blocks of British camaraderie…
- …and consequently flew a training jet through the eye of an approaching hurricane in July 1943. Miraculously, he survived.

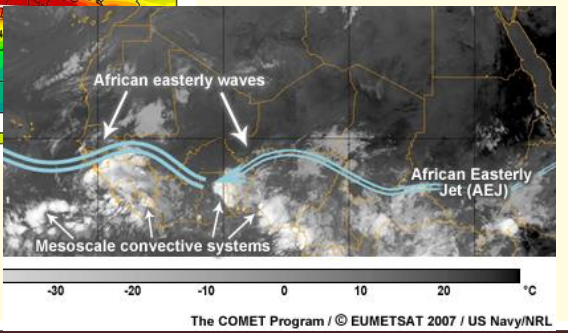
- On returning to the airbase, a very upset meteorologist convinced him to do it again immediately…
- …giving rise to annual hurricane reconnaissance missions from 1944 onwards.
- In the now 70 year history of Atlantic hurricane reconnaissance flights, only one plane has been lost – in the Category 5 Hurricane Janet, 1955.

Atlantic Hurricanes:
Formation and Prediction

The Tropics: Easterly waves



- In Summer: Sahara = hot, Atlantic = relatively cool.
- This sets up a flow of air from the east.



- The jet is highly unstable, resulting in successive wave (trough/ridge patterns)

The COMET Program / © EUMETSAT 2007 / US Navy/NRL

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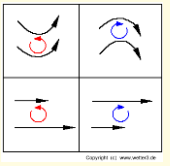
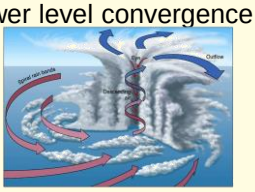
The Perfect Storm

- 1) High Cyclonic Vorticity

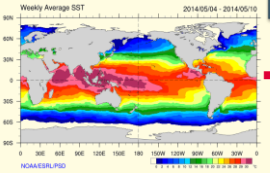


- 2) Upper level divergence & Lower level convergence

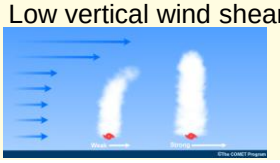


What conditions turn a Mesoscale Convective Cluster into a Hurricane?

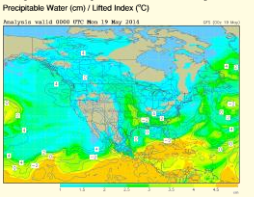
- 5) High (>26°C) SSTs



- 4) Low vertical wind shear



- 3) Deep moist layer



Mesoscale Convective Cluster → Tropical Cyclone

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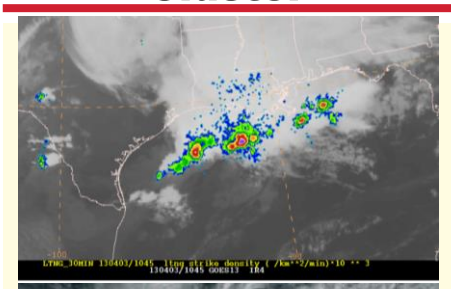

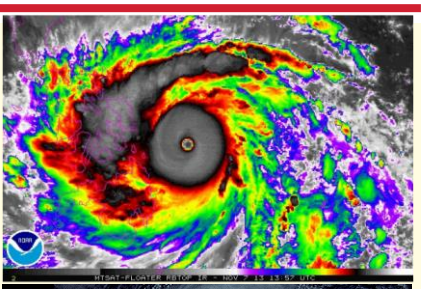

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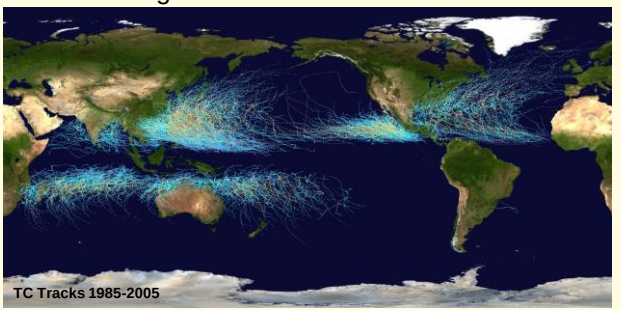
Forecasting: Genesis and Track

- Although we know what the conditions that can give rise to hurricanes are,
- "The general problem of tropical cyclogenesis remains, in large measure, one of the great mysteries of the tropical atmosphere."

- Kerry Emanuel, MIT.

- ~85 Tropical Cyclones form globally each year, of which around half will become hurricane strength.



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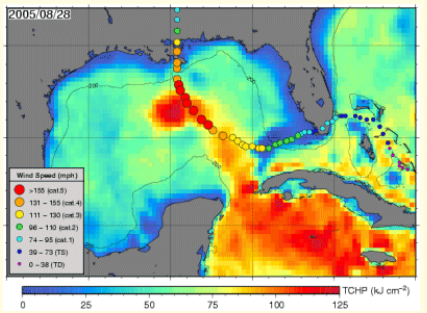
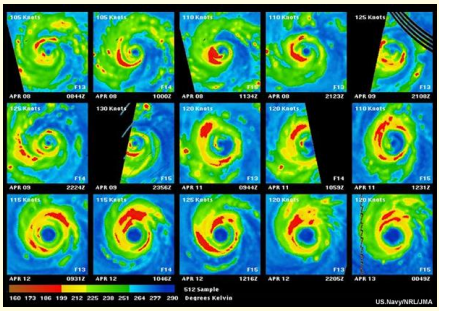
Forecasting: Rapid Intensification (RI)

- RI = increasing windspeeds by 35mph or more in 24hours.
- Can occur in two main ways:
- **1) Extremely high SSTs (>30°C) extending over a deep ocean layer**



- **2) Eyewall Replacement Cycles**



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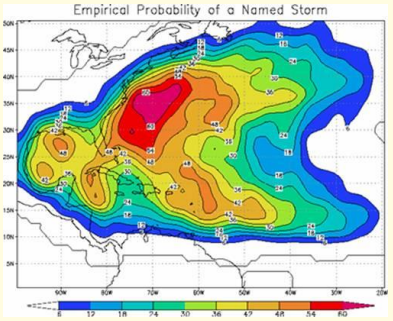
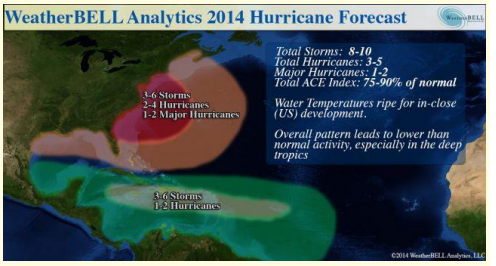
Seasonal Prediction

- Relatively little is known about prediction on a seasonal timescale, especially for US landfall.
- Most prediction systems rely heavily on monthly SST & ENSO forecasts.





- However, lots of promising research is being undertaken into seasonal steering winds and genesis locations that could be useful in the near future…

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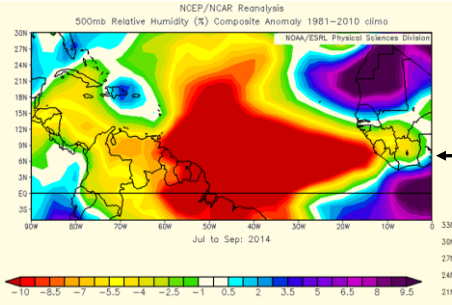
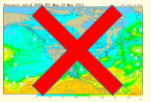
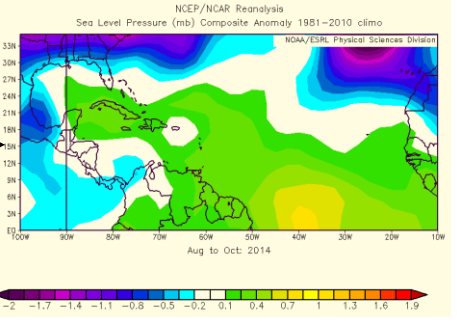
2014 Predictions: Below Average



- 3) Deep moist layer



Mid-level humidity anomaly



Sea level pressure anomaly

- 2) Upper level divergence & Lower level convergence

Past predictions: Colorado State

	Total Named Storms		Total Hurricanes	
Year	Predicted	Observed	Predicted	Observed
2010	16	17	9	11
2011	12	15	9	7
2012	10	15	5	9
2013	14	9	8	2
2014	9	7	3	5
Average (1984-2014)	**10.9**	**10.8**	**6.3**	**6.1**
1984-2014 Correlation		**0.59**		**0.51**

2013 Failure?

"The best laid schemes of mice and men sometimes go awry"

-- R. Burns

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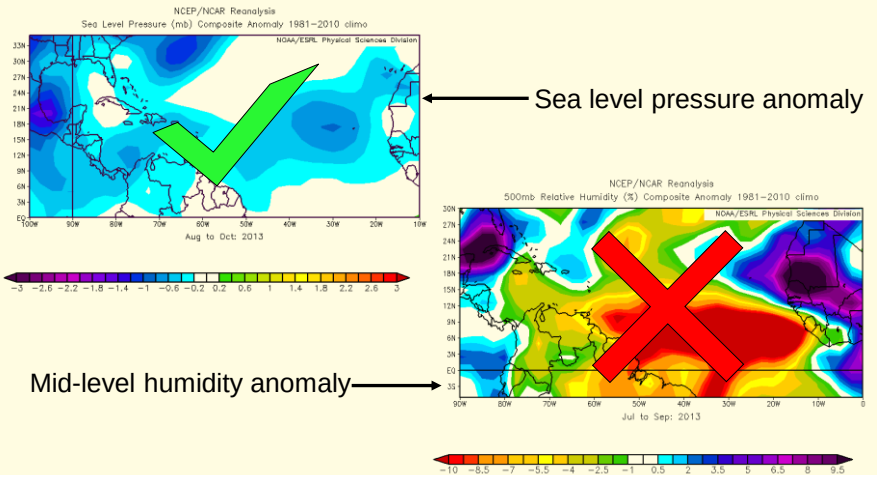
2013 Failure – Why?



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Seasonal Prediction: Overall

- **Although short-term forecasting is progressing rapidly, accurate seasonal prediction still remains a way off due to incomplete understanding of oscillations that govern overall activity.**

- **To add to the natural variability issue, there is also the issue of the potential of climate change imparting a trend onto hurricane activity.**

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Atlantic Hurricanes & Climate Change

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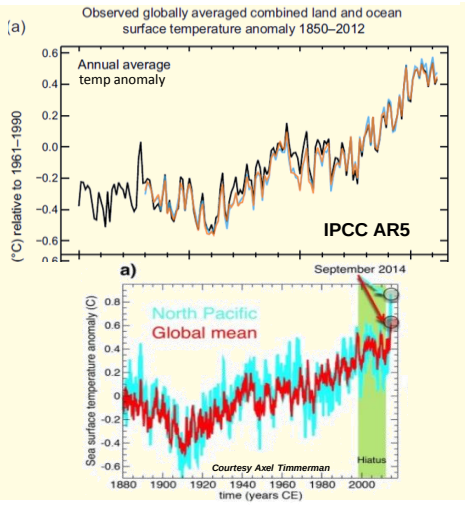
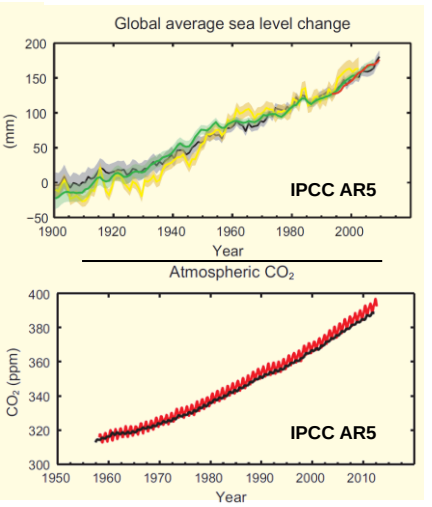
Anthropogenic Climate Change is undeniable





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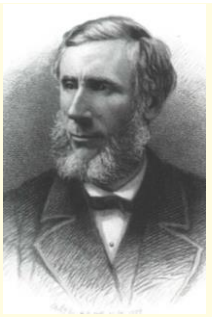
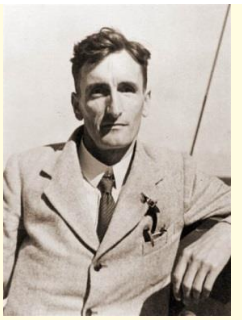
How do we know that?



- John Tyndall, 1820-1893
- Measured heat absorption by various gases.
- In 1861 showed that water vapour absorbed the most heat compared to other atmospheric gases.

- Svante Arrhenius, 1859-1927
- Attempted to quantify the contribution of CO_2 to what he called "the greenhouse effect".
- Was the first to note that there is a human contribution due to industrialisation.



- Guy Callendar, 1898-1964
- First to suggest that CO_2 was responsible for some warming that had been observed in climate records.
- Concluded that this was good, as "the return of the deadly glaciers should be delayed indefinitely."

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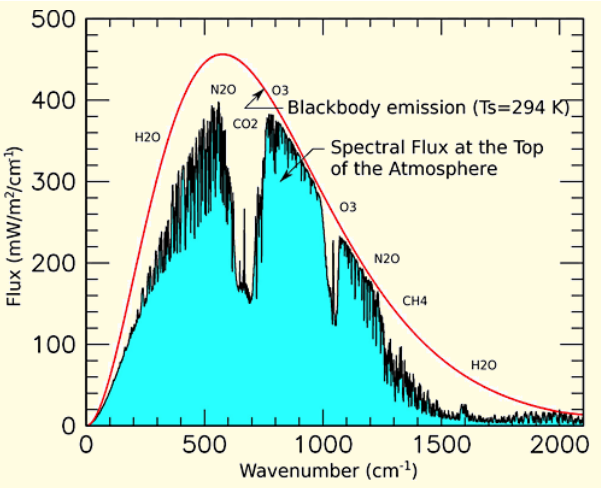
Earth's Emission Spectrum



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HOWEVER:

Climate is NOT Weather

How anthropogenic climate change affects severe weather events remains highly uncertain

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Climate Change and Hurricanes:

- From contemporary climate change projections, there are 3 large scale changes that look likely to impact Atlantic hurricane formation:
  - 1) Increased Sea Surface Temperatures:
    - ★ Greater Area for hurricanes to form over
    - ★ Increased intensity potential from deeper warm ocean.
  - 2) Increased vertical wind shear:
    - ★ Much like an El Niño event
    - ★ Decreased chance of hurricane formation.
  - 3) Decreased humidity:
    - ★ Drier mid-layer of atmosphere
    - ★ Decreased chance of hurricane formation.

Ocean Basin	Ocean Warming	Wind Shear	Relative Humidity	Overall effect on TC numbers/intensities
Atlantic/E. Pac	Increase	Increase	Decrease	???
W. Pac/Indian	Increase	Decrease	Increase	INCREASE

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Atlantic Hurricanes:
Where do records come from?

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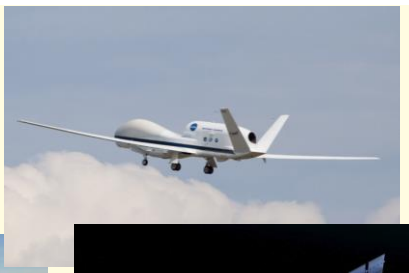
Modern Flights and the Satellite Era



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Pre Flights and Satellites?

Courtesy NOAA

Wreck of the Sea Venture, by Christopher Grimes

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The Hall of Records

- ***Homer*** : Oh Lisa, there's no record of a hurricane ever hitting Springfield.
- ***Lisa***: Yes, but the records only go back to 1978 when the Hall of Records was mysteriously blown away!

- The Simpsons

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The Atlantic Hurricane Record: HURDAT

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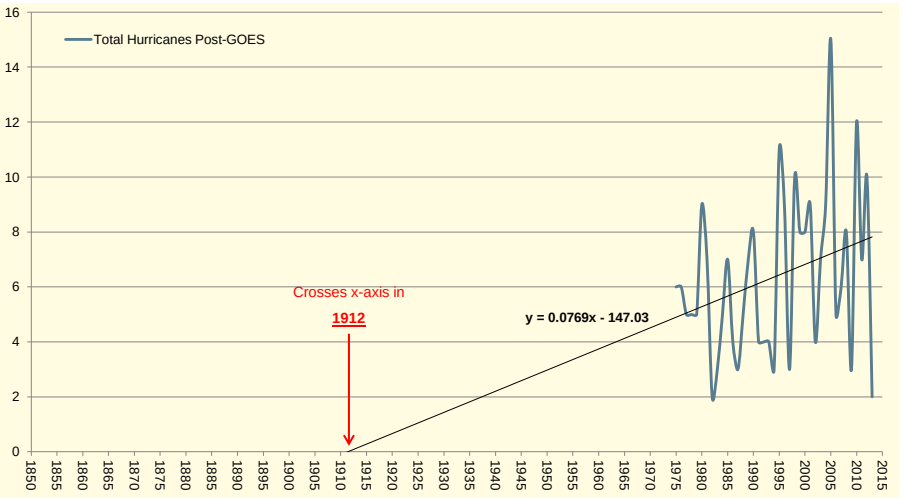
Total Hurricanes, Post-GOES (1975)



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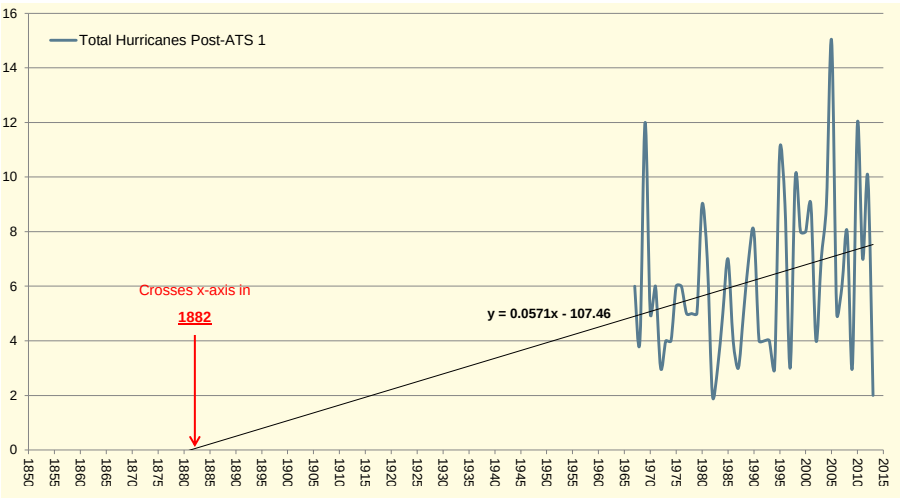
Total Hurricanes Post-ATS 1 (Dec 1966)



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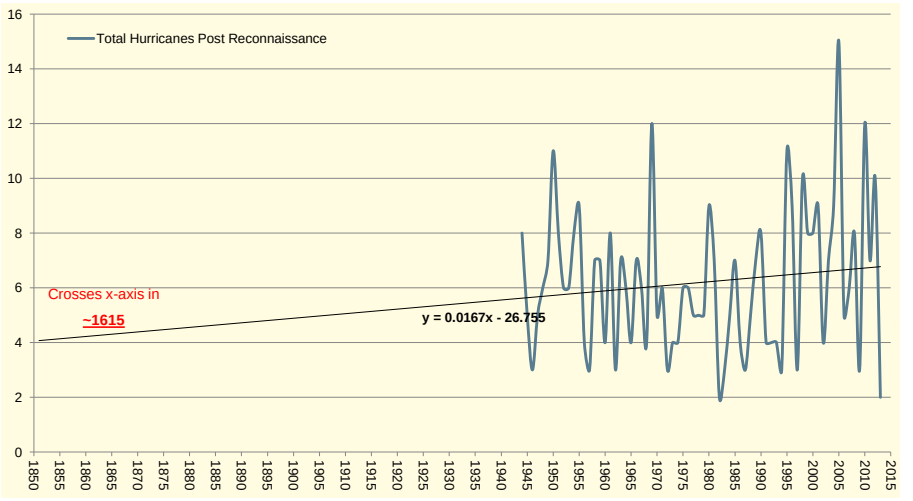
Total Hurricanes Post-Reconnaissance Flights (1944)



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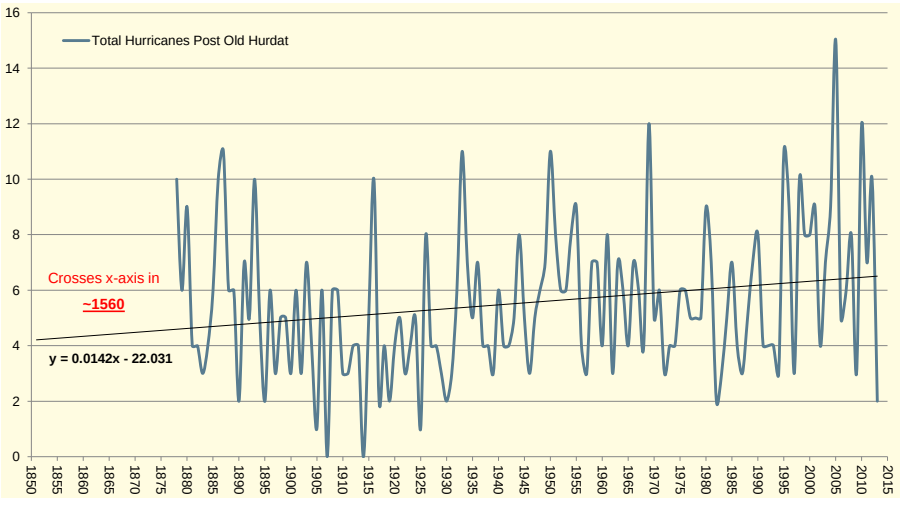
Total Hurricanes Post-Old Hurdat (1878)



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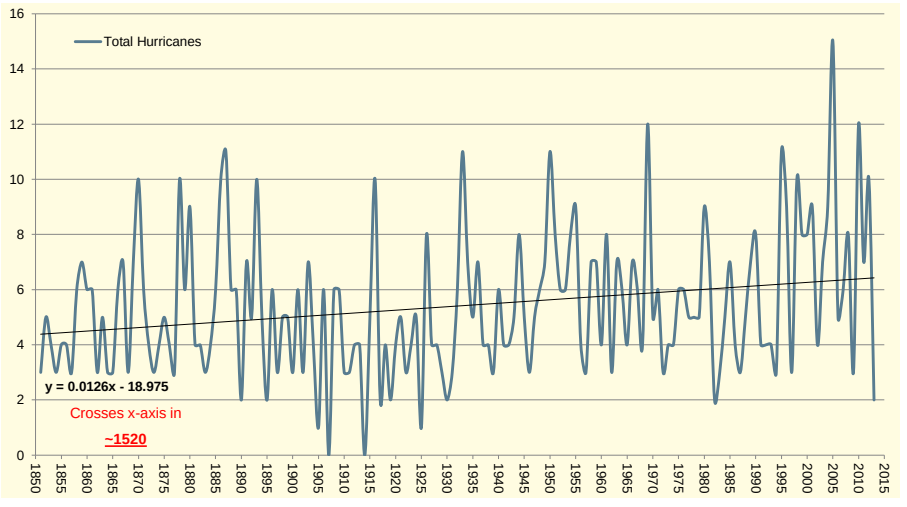
Total Hurricanes, current HURDAT



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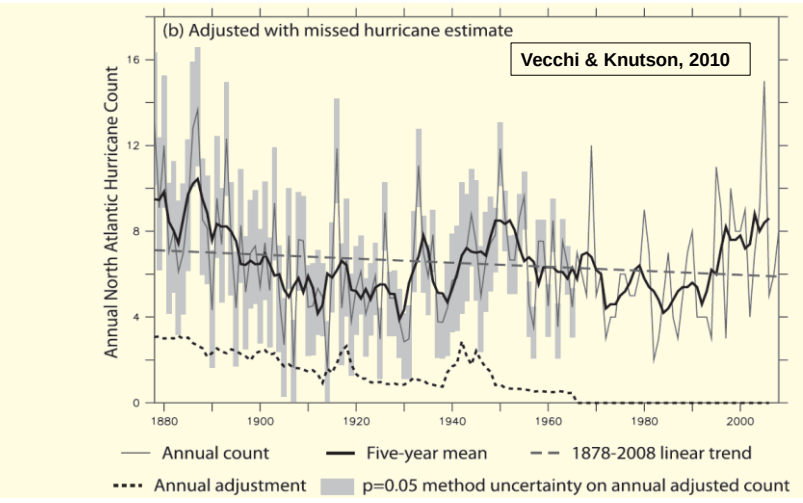
Adding in "Missing" Storms pre-ATS 1



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Why Use Windspeed?

- Only 3 of the 10 deadliest US storms were "major" hurricanes (i.e. Category 3 or higher) at landfall.
- 6 of the 10 deadliest were Category 1 at landfall.

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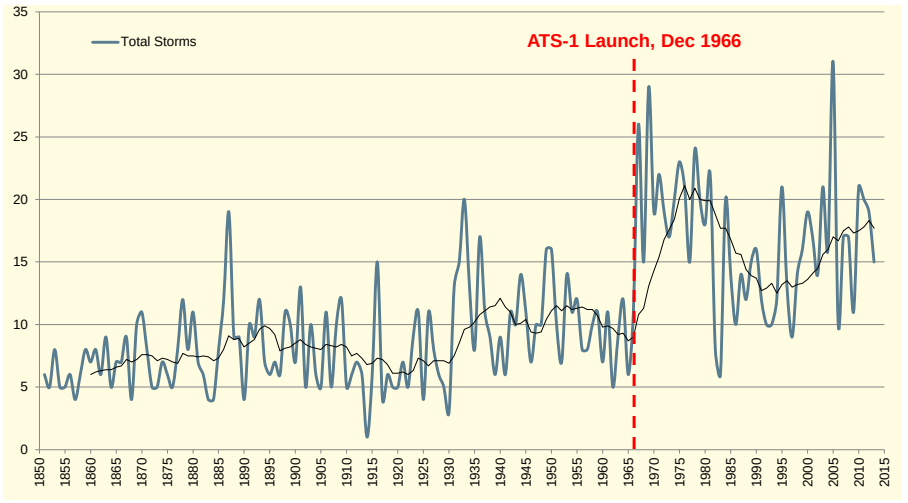
HURDAT Total Tropical Storms Per Year



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Historical Hurricanes

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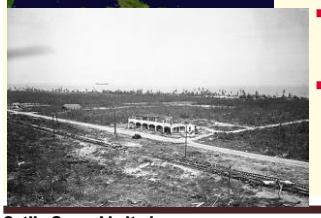
Case Study: Labor Day Storm, 1935

- Relatively Small: ~250km wide.
- BUT very intense – estimated winds of 200mph and storm surge of 15-20ft.
- Every single tree and building on Matecumbe Key disappeared, ~$103million in 2014 currency.
- The majority of the population of the middle Florida Keys lost their lives, as well as a substantial fraction in the Northern Keys.



- 259 US veterans who had been tasked with building a highway linking the keys also died.
- "Ignorance has never been an excuse for murder or manslaughter."

- Ernest Hemingway in an open letter to FDR's government

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Case Study: Hurricane Camille, 1969

- Rapidly intensified shortly before landfall to a category 5 hurricane near Bay St. Louis in Mississippi, ~50miles east of New Orleans.
- 190mph winds and a 22.6ft storm surge, the highest in the US until Katrina.
- Flattened nearly everything in its path.
- 259 dead, $9.13 billion damages in 2014 currency.

Motels West of Biloxi, Mississippi

- "Many were warned to evacuate. Some refused. Some did leave and returned. Everyone thought their houses and buildings were safe because they'd survived the last bad hurricane 22 years earlier." - *Julie Guice, Civil Defense Director for Biloxi, Mississippi*

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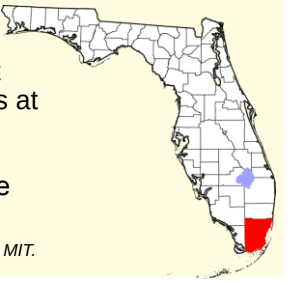
Case Study: Great Miami Hurricane, 1926

- Made landfall as category 3, max wind 128mph, storm surges of 8-15ft.
- Much of downtown Miami and Miami beach lay in ruins.
- It caused ~$2billion damages in 2014 currency.
- "In the 40 years from 1926 to 1966, Dade County, Florida, was struck by hurricanes 13 times. But there were no hurricanes at all for the next 25 years, during which time the county's population more than doubled."

- Kerry Emanuel, MIT.



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The US Hurricane Loss Record

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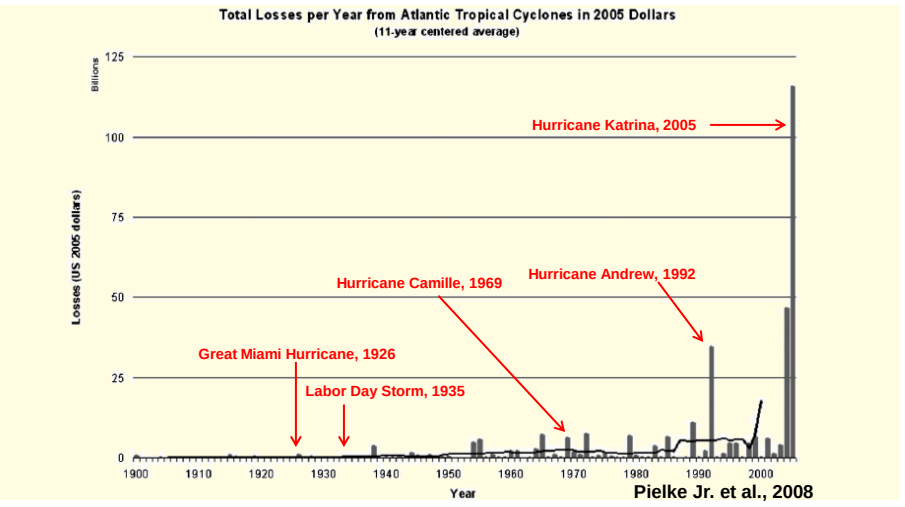
Inflation Adjusted losses



Pielke Jr. et al., 2008

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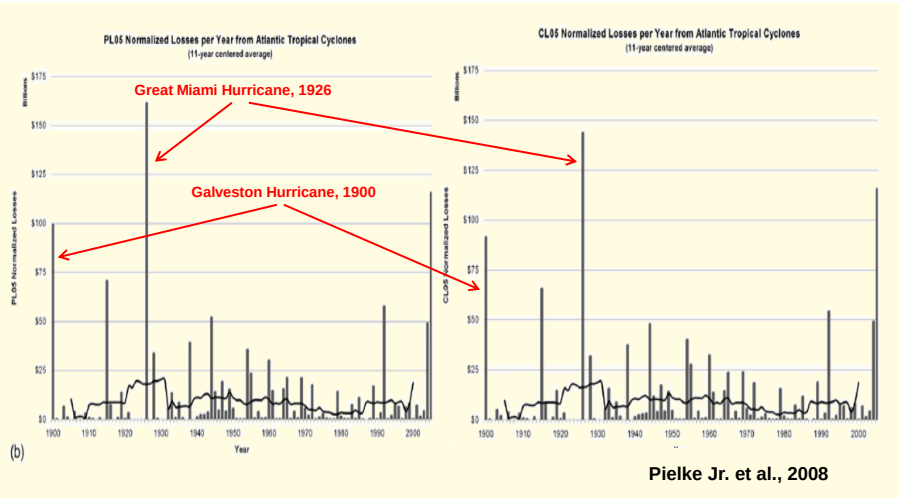
Normalized losses



Pielke Jr. et al., 2008

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Conclusions

- Although it is indisputable that it is occurring, Climate Change is ALMOST CERTAINLY NOT the main driver of the increase in Atlantic hurricane losses in recent years.

- The main cause of this is much more likely the almost exponentially increasing VULNERABILITY of our insured societies.

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Thanks for Listening.

Questions?