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Hurricane Clustering: A New Reality?

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The views in the presentation are the views of the presenter and not necessarily those of his employer

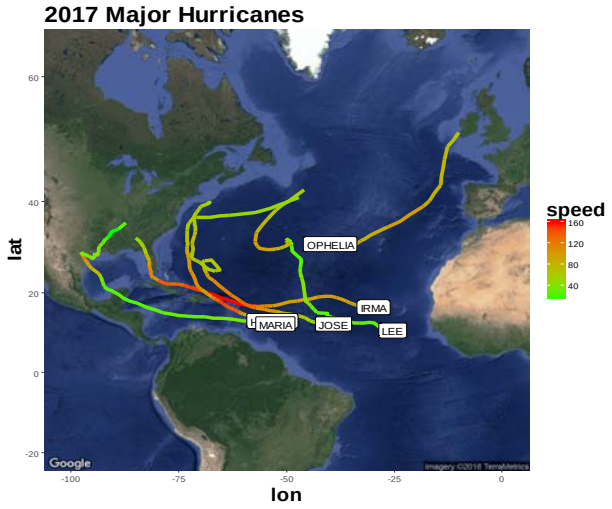
Based on the Bank Underground article

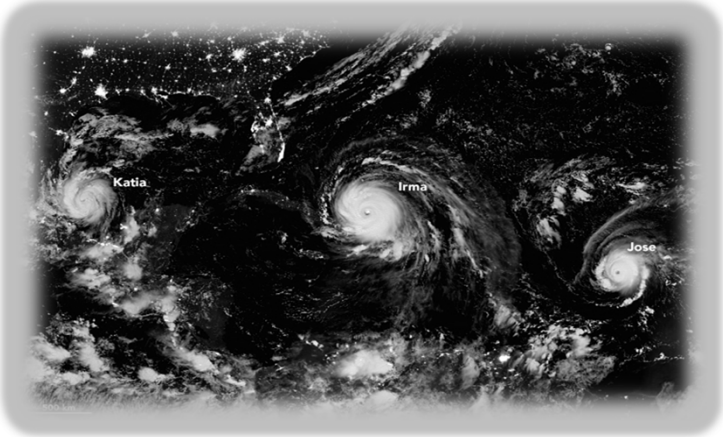
https://bankunderground.co.uk/2018/05/22/us-hurricane-clustering-a-new-reality/

by Alex Ntelekos, Dimitris Papachristou and Juan Duan

Questions to be discussed

- Has the frequency of North Atlantic hurricanes increased?
- Do hurricanes come in clusters?
- Why were hurricane losses relatively low in previous years (2006 – 2016)?
- What are the implications of the above?





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How is this different from other work?

- Climatologists focus more on the physics of hurricanes
- Updated work of academics
- We focus on insurance related issues
  - Major hurricanes
  - High level validation
  - Impact

What do we cover?

- Groups of major hurricanes
  - Climatology and Features
- Change in frequency and volatility over time
  - Actual vs Modelled
- US Landfalls
- Implications

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What are we analysing?

- major hurricanes in some point in their lives (cause most of the damage),
- which make landfall in Continental US

Focus on frequency, but frequency NOT the only factor:

Location and Exposures	• Hurricane Sandy (2012) made landfall in NJ, NY and CT as a tropical storm, but exposures were high, size was huge, tide was high and surge
Intensity at Landfall	
Rainfall, Surge and Flooding	• The majority of fatalities is caused by flooding and surge • Flooding is not covered for residential properties
Size of hurricane	• The larger the hurricane, the larger the affected area and the longer it takes it to pass through an area
Forward speed of hurricane	• The forward speed of the hurricane adds to their anti- clockwise wind speed. Slow down increase rain damage
Other	

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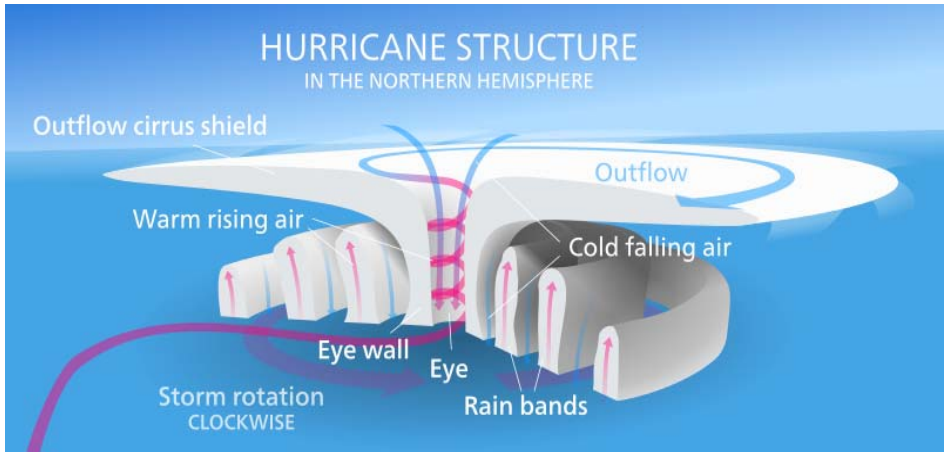
Tropical Storms, Hurricanes, Major Hurricanes



Tropical cyclone categories (Saffir-Simpson)

- **Tropical Depression (<34kn or <63km/h)**
- **Tropical Storm / named storm (34 – 63kn or 63-118 km/h)**
- **Hurricane:**
  Cat 1 (64-82kn or 119-153 km/h) and
  Cat 2 (83-95kn or 154-177 km/h)
- **Major Hurricane:**
  Cat 3 (96-112kn or 178-208kmh),
  Cat 4 (113-136kn or 209-251kmh),
  Cat 5 (>136kn or >252kmh)

- **An efficient heat engine (see Emanuel K. (2006))**

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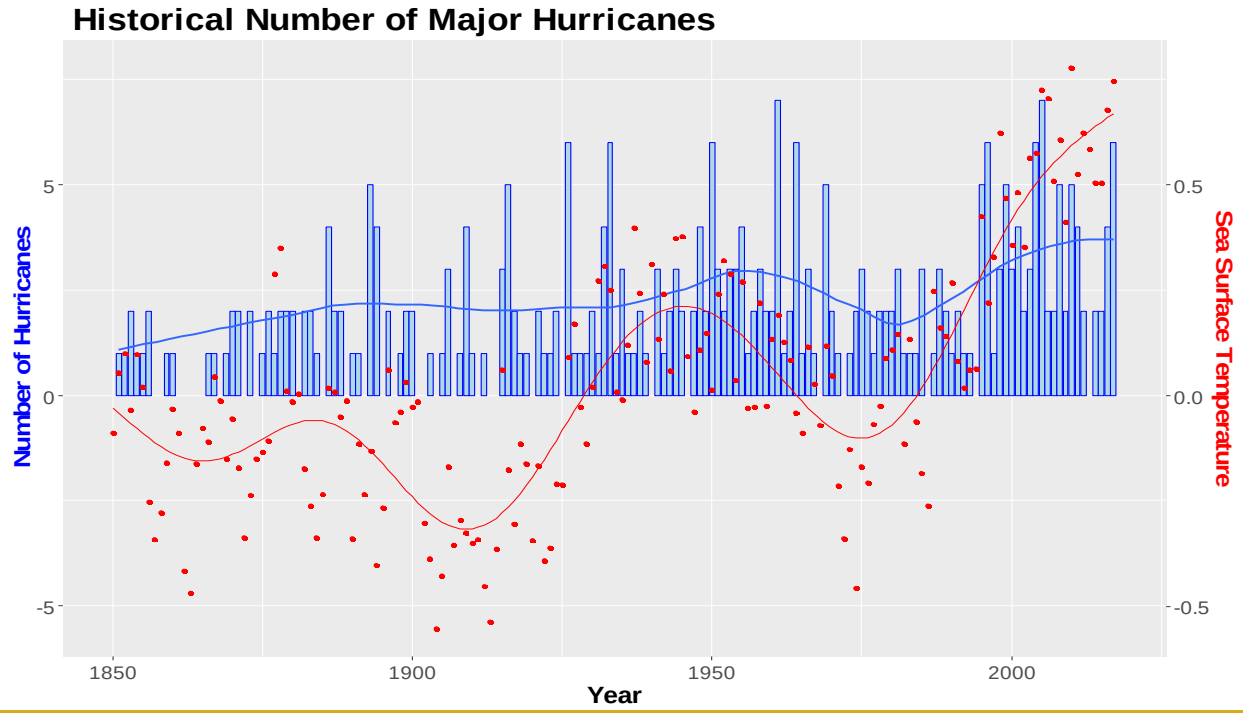
Major Hurricanes Frequency follows North Atlantic Sea Surface Temperature?

- Atlantic Multi-decadal Oscillation (AMO), sulphate aerosols in atmosphere



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Issues with the Data

Hurricane data (HURDAT)

- Aircraft Reconnaissance in the 40s
- Satellite imaging in the 60s
  - micro wave and GPS waves
- Possible missing hurricanes before 50s

Sea Surface Temperature data (NOAA SST)

- Ships: wooden buckets or engine room
- Satellites: radiation
- Floats and drifts complimenting each other
- Different sea depths

Records for only three peaks of SST cycle

- Scientist use indirect methods to extend the period over which have information on SST and hurricanes (paleotempestology)

We analyse Major Hurricanes after 1950

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Hurricane Groups and their Climatology

Hurricane Groups

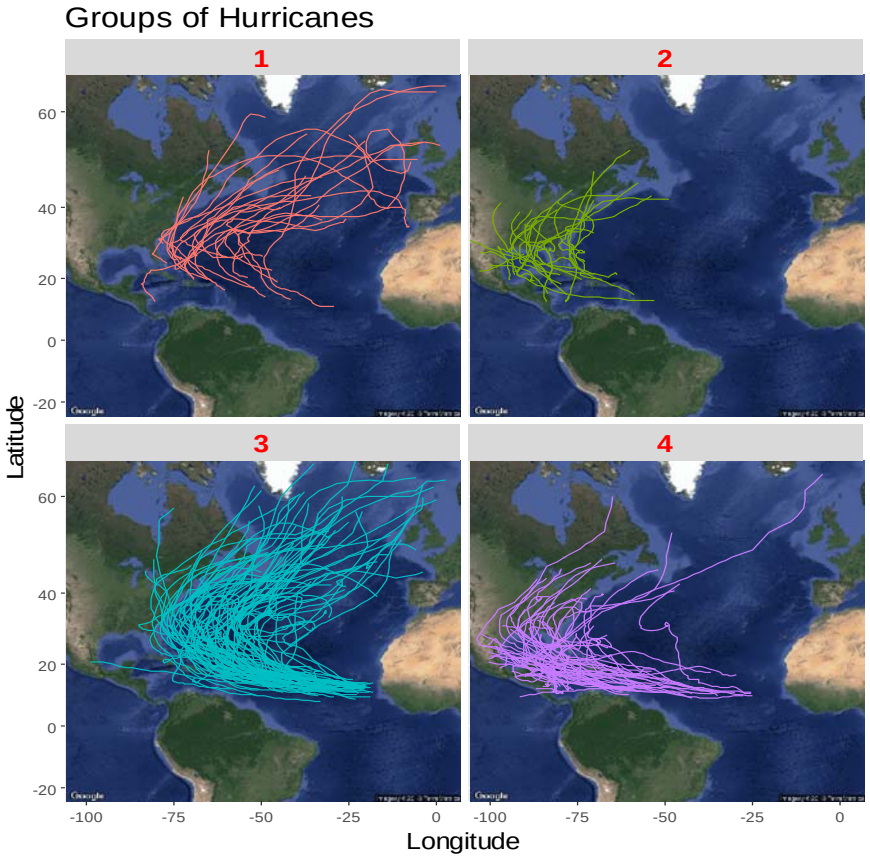
Different statistical clustering methods give different groups of hurricanes

Hurricane Groups were created by statistical cluster analysis by Professor Suzanna Camargo http://www.ldeo.columbia.edu/~suzana/

and Dr James Kossin http://www.ssec.wisc.edu/~kossin/

updating their 2010 paper to include hurricanes up to and including 2017

https://journals.ametsoc.org/doi/10.1175/2010JCLI3497.1



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Climatology of Hurricane Groups

Group 2

Gulf, no time to gather energy

High probability of landfall

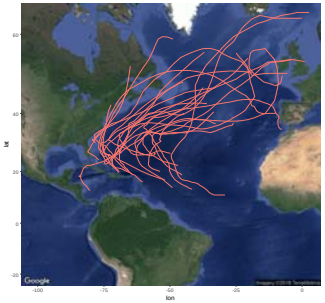
Example: Katrina, Harvey

Group 1

Further from the Equator,

usually not very strong,

curve up, few landfalls



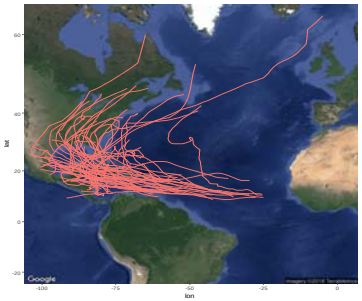
Group 4

Near the equator and west

straight paths

towards Florida and Gulf

Example: Andrew, Irma, Maria



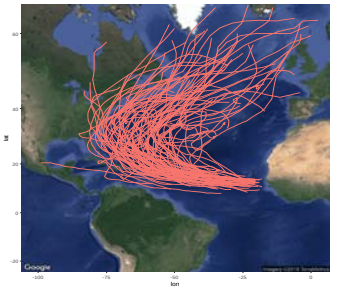
Group 3

Near the equator and east

time to gather energy,

curve up

Example: Hugo, Florence



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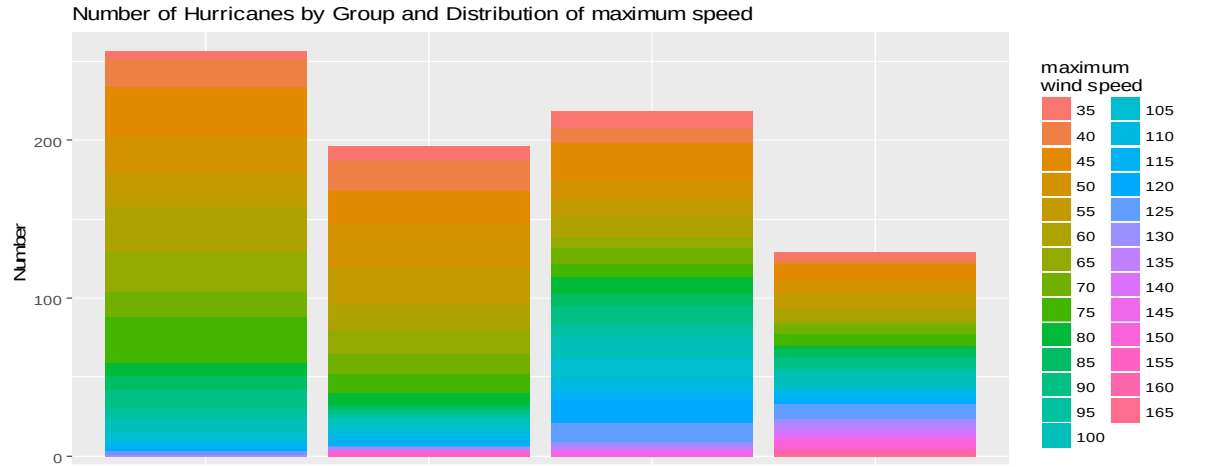
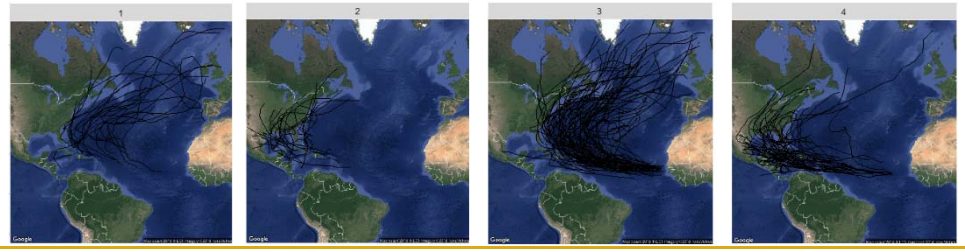
Groups 3 & 4 stronger hurricanes – Group 2 many landfalls



	Group 1	Group 2	Group 3	Group 4	All
# of major hurricanes	23	24	76	53	**176**
US landfalls	5 (22%)	21 (87%)	16 (21%)	27 (51%)	**69 (39%)**



green and below is a hurricane

blue and below is a major hurricane

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Hurricane Groups

Grouping of hurricanes helps analysis and understanding

- Climatology (location, SST, energy, etc.)
- Areas of landfall and intensity
- Probabilities of landfall
- Different groups are affected by different factors

Statistical Cluster Analysis

- Grouping not unique, it depends on the statistical clustering method and parameters

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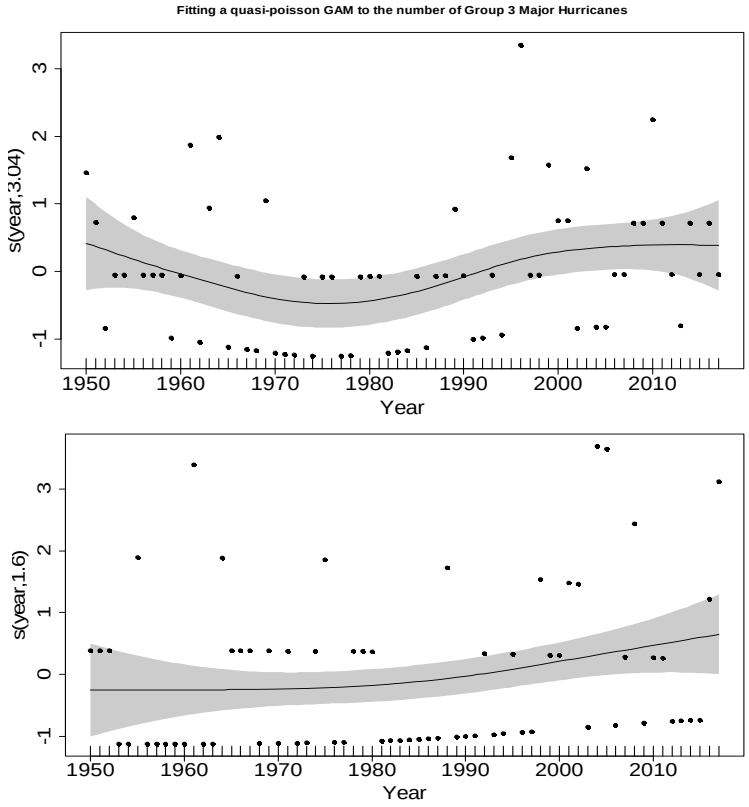
Has the Frequency of Major Hurricanes Increased?

Numbers and Volatility of major HU have been increasing (groups 3 &4)

Groups 1 & 2 fairly stable, small reduction

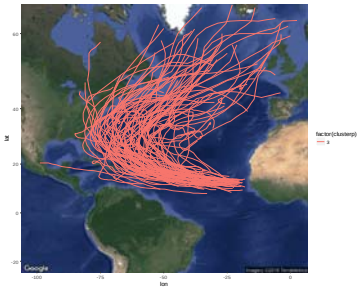
Log Scale



Group 3:

Cycle?

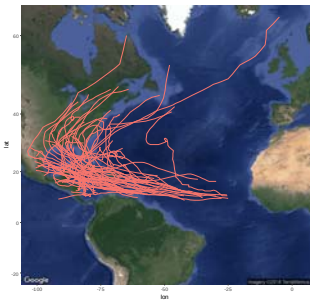
Poisson



Group 4:

Significant increase

Volatility higher than Poisson



Shadows: 95% C.I.

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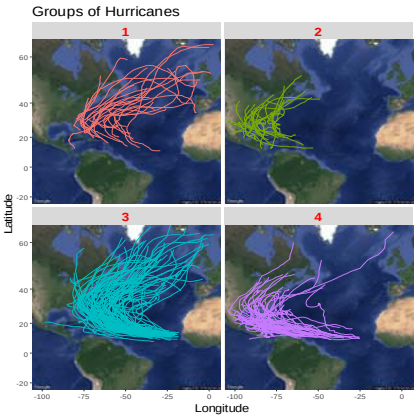
Probability of multiple continental US landfalls of major hurricanes in a year

Actual Continental US Landfalls since 1950
Not many years with multiple events

Major* Hurricanes US Landfalls 1950 - 2017				
Regional Groups	Number of Years		Return Periods	
	2+ major hurricanes	3+ major hurricanes	2+ major hurricanes	3+ major hurricanes
Group 1	0	0		
Group 2	2	0	1 in 34	
Group 3	2	0	1 in 34	
Group 4	6	1	1 in 11	1 in 68
All Groups	18	5	1 in 4	1 in 14

* Major at some point in its lifetime



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Modelled Current Frequency higher than Actual since 1950

Regional Group	2 or more major* hurricanes making landfall in the US		3 or more major* hurricanes making landfall in the US	
	Modelled	Actual	Modelled	Actual
Group 1	1 in 400	<1 in 500		
Group 2	1 in 25	1 in 34	1 in 250	
Group 3	1 in 20	1 in 34	1 in 180	
Group 4	1 in 7	1 in 11	1 in 30	1 in 68
All Groups	1 in 2.5	1 in 4	1 in 7	1 in 14

* Major at some point in its lifetime

Assumptions:

- Probability of landfall constant over time. We will revisit
- Group frequency assumed independent
- Negative Binomial for Group 4, Poisson for the other Groups

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Recent Trends: Higher Number and Volatility

Increased expected numbers of major hurricanes (groups 3 &4)

- Group 3 and 4 hurricanes can hit areas with high exposures

Higher volatility in the number of Florida/Gulf hurricanes

- Giving rise to years with multiple major hurricanes (clustering)

Implications (discussion at the end)

- Parameterisation of cat models
- Risk management

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Do major hurricanes occur close to each other in time?

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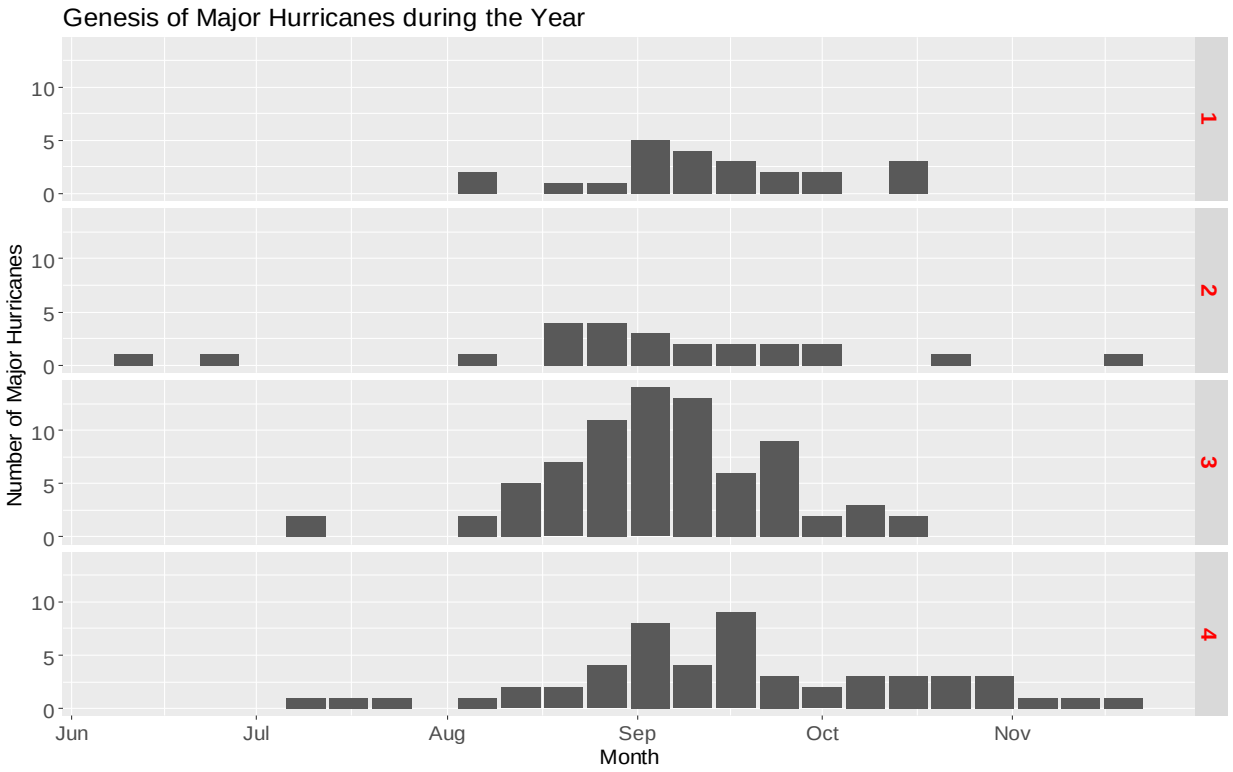
Most major hurricanes occur between mid-August and end-September



Peak 1st part of September

Groups 1&2 more spread over the year

Group 3 more concentrated in a few weeks

Group 4 two peaks

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Do hurricanes come in clusters?

Most major hurricanes occur in the short period mid-August to mid-September

- it is likely that major hurricanes will occur close in time

Experiment

- Assume independent daily increments ($\sim Poisson(\lambda_t)$):
- Result: probability of around 50% that Group 3 hurricanes will occur within two weeks of each other
- given that more than two hurricanes occur in a year, it is likely that they will occur close to each other

Implications for operational preparedness

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If frequency has increased, why was 2006 to 2016 a relatively quiet Hurricane period then?

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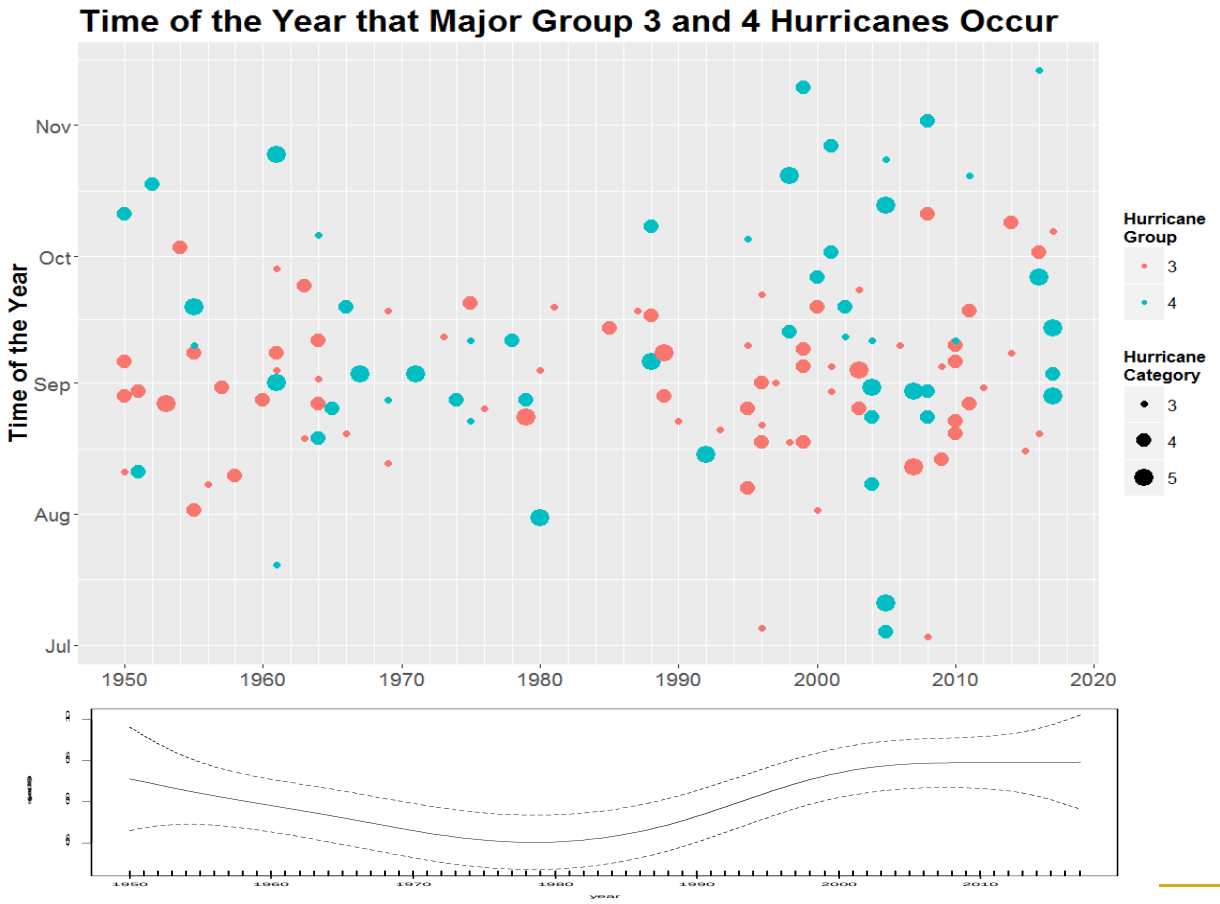
Why were hur. losses not very high in 2006 – 2016?

Some suggestions:

- Luck?
- Frequency not the only factor
- High volatility (not Poisson) of Group 4 hurricanes?
- Probability of landfall changed?
  - High frequency years => hurricanes with different features?
  - Does Mother Nature protect the US?
  - Have maximum speeds locations moved eastwards?
- Negative correlation in frequencies of Group 3 and 4 hurricanes?
- El Nino?
- Other?

Hurricane season extended in high frequency years



Time of the Year that Hurricanes Occur

In high frequency years group 4 hurricanes likely to also occur in October

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Late major Hurricanes usually in Caribbean

Most of the late Major HU start in the Caribbean (group 4) and

have paths which tend to go north and east

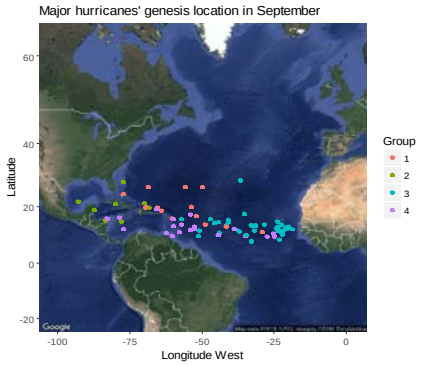
with lower probability of hitting the US

However, they could hit Florida or Gulf

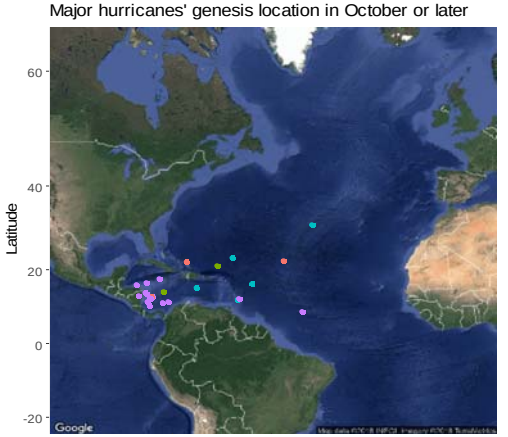
They can **intensify very quickly**.

Be ware of the late hurricanes

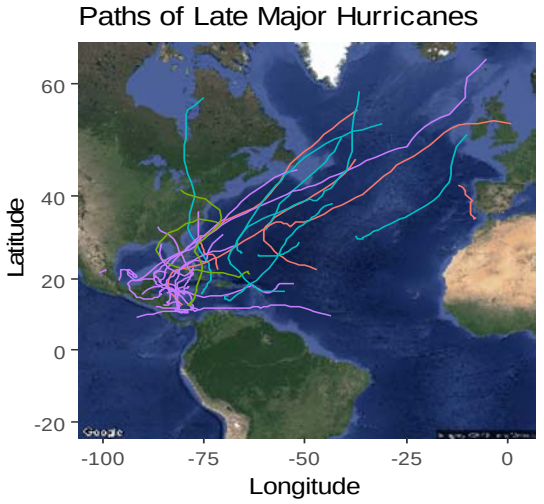
Wilma 2005, Michael 2018



September genesis



October genesis



October paths

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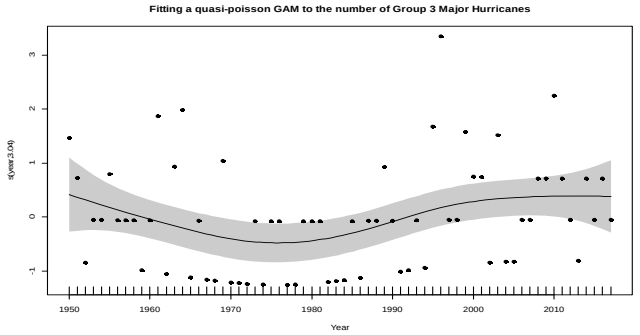
Does Mother Nature protect the US East Coast?

Kossin in https://www.nature.com/articles/nature20783

suggests that intensification of hurricanes near US weakens in years of high activity

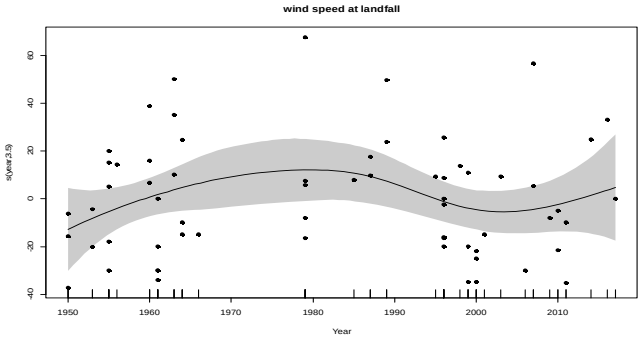


some support by graphs:

Spline for

(wind speed at landfall~s(year))

not statistically significant



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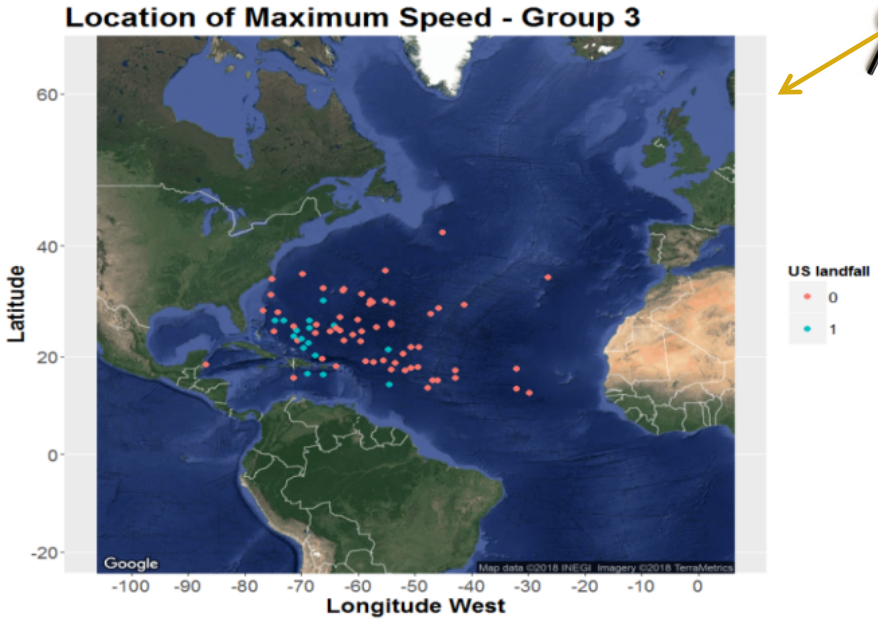
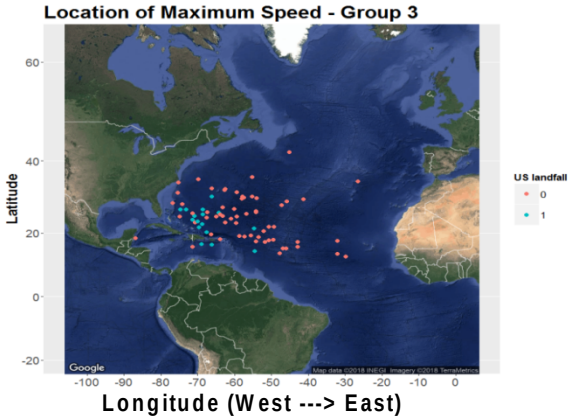
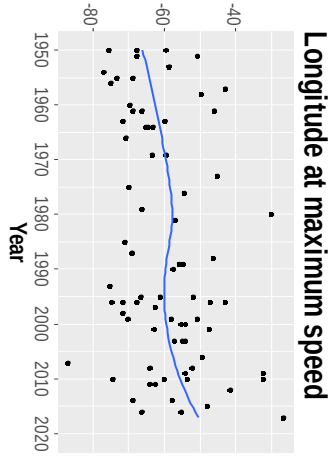
Eastwards Trend of the maximum speed location =>
Less likely to hit the US?







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Period 2006 – 2016 fairly benign

Over dispersion of Group 4 hurricanes

In high frequency years we observe October major hurricanes

- most of them wonder off to the North Atlantic and do not hit the US

Mother Nature protects the US east coast?

- Inverse relation between SST and vertical wind shear near the US (Kossin (2017))

Maximum speeds locations have moved eastwards

- this may have slightly reduced the probability of landfall?

There is some evidence (not strong) of some “crowding out”

- There is a slight negative correlation between the number of Group 3 and 4 major hurricanes in a year recently

Lucky?

Implications of the observed trends in frequency (1)

- Choice of model parameters
  - Long term versus short term assumptions
- Choice of Stress Tests
- Communication of uncertainty
  - Communication to the Board
  - Communication between experts
- Validation
  - How are cat models validated independently?
- Should we aim for more integration of climate models with statistical models?

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Implications of the observed trends in frequency (2)

- Risk management
  - Impact on capital requirements, impact on capital management
- Reinsurance cover and pricing
  - Sideways exhaustion of reinsurance (October hurricanes)
  - Aggregate covers
- Operational preparedness
  - Claims management, risk adjusters, additional costs
- Other implications for society: storm surge and flooding

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Summary

Both expected frequency and volatility of major hurricanes have increased

- Groups 3 and 4 major hurricanes can cause significant insurance losses

Major hurricanes are likely to occur closely to each other in time

There are implications for

- Choice of model parameters and communication of model parameters
- Choice of Stress Tests
- Risk management
- Capital requirements and capital management
- Reinsurance pricing and cover?
- Operational preparedness

Statistical analysis can group together hurricanes with similar climatology

- Grouping can help understanding and analysis

How could we best combine weather/climate models with statistical models?

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Questions

Comments

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Appendix
Most major HU at some point in lifetime make landfall at least as HU

- Major HU at some point in their lives do not necessarily make landfall as major HU.