Major Hurricanes in the North Atlantic

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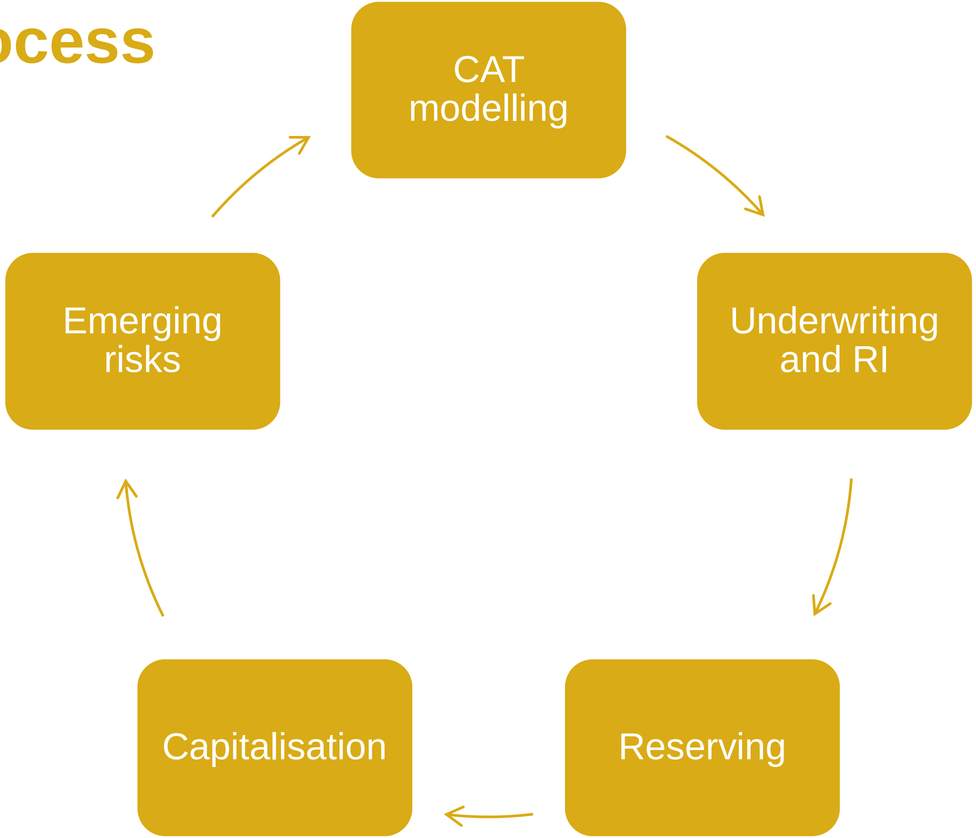
Contents

Introduction and purpose of the WP

01 October 2019

A typical process



Purpose of the WP

- Key objective of the working party is to connect the catastrophe models to the commercial and actuarial world
  - Our work is designed to enable the key decision makers (C-suite) in the business understand and take underwriting, actuarial and risk management decisions, especially after the occurrence of major hurricanes
- The research is restricted to hurricanes in the North Atlantic ocean
- Our work is structured around 3 workstreams
  - Definition: high-level definition of the hurricanes and a brief description of the cause
  - Key drivers: Possible reasons to increase uncertainty in catastrophe modelling
  - Market response: The reaction observed in different areas of business following an event

Structure of the research

Definition

- What is a hurricane?
  - How is a major windstorm defined?
- What is the cause of a hurricane?
  - Impact of El Nino/La Nina
- How are hurricanes modelled in vendor models?
- What is the scope of this research

Key causes

- Clustering
- Non-modelled catastrophe
- Impact of climate change

Market response

- Reinsurance/Underwriting strategy
- Reserving
- Any changes in catastrophe modelling
- Risk management

Hurricanes: definition, formation and impact

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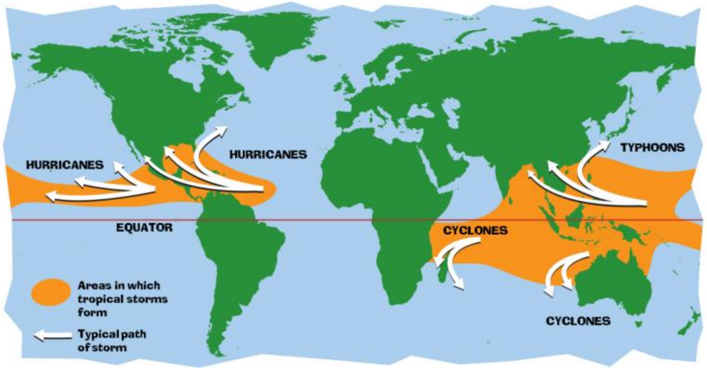
Definitions



Hurricanes are tropical storms that form over the North Atlantic Ocean and Northeast Pacific.

Cyclones are formed over the South Pacific and Indian Ocean.

Typhoons are formed over the Northwest Pacific Ocean.

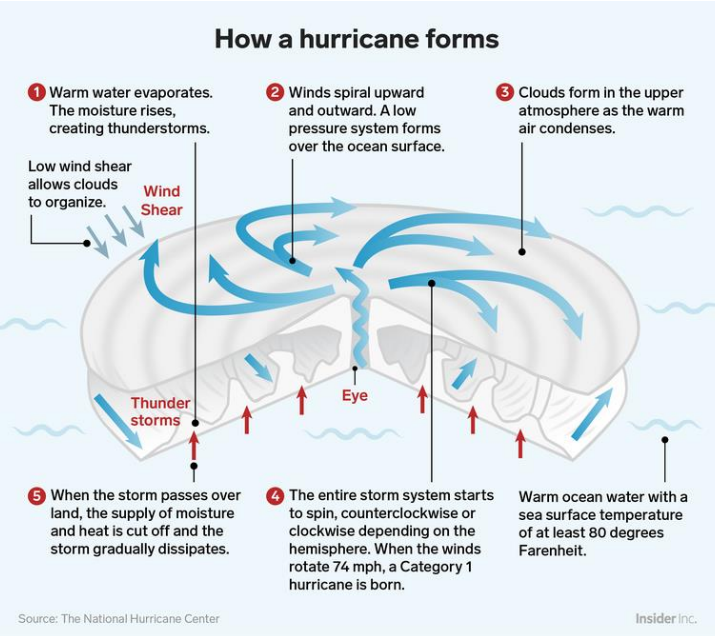
Saffir-Simpson Hurricane Wind Scale classifies hurricanes into five categories distinguished by the intensities of their sustained winds.

Saffir-Simpson Hurricane Wind Scale				
	Wind speeds(for 1-minute maximum sustained winds)			
Category	m/s	knots (kn)	mph	km/h
Five	≥ 70 m/s	≥ 137 kn	≥ 157 mph	≥ 252 km/h
Four	58–70 m/s	113–136 kn	130–156 mph	209–251 km/h
Three	50–58 m/s	96–112 kn	111–129 mph	178–208 km/h
Two	43–49 m/s	83–95 kn	96–110 mph	154–177 km/h
One	33–42 m/s	64–82 kn	74–95 mph	119–153 km/h
Tropical storm	18–32 m/s	34–63 kn	39–73 mph	63–118 km/h
Tropical depression	≤ 17 m/s	≤ 33 kn	≤ 38 mph	≤ 62 km/h

Formation

- There are a number of key factors contributing to the formation of a hurricane:

- **Sea surface temperature** of at least 26.5°C are needed down to a depth of at least 50 m;
- **Rapid cooling of air with height**, which allows the release of the heat of condensation that powers a hurricane;
- Low amounts of **wind shear**, as high shear is disruptive to the hurricane's upwards circulation;
- **Coriolis force** which deflects the winds and creates a horizontal circulation;
- **Pre-existing disturbed weather**, hurricanes evolve from smaller storms.



Perils

Wind damage

Strong winds can damage or destroy vehicles, buildings, bridges, trees, personal property and other outside objects, turning loose debris into deadly flying projectiles.

Hurricanes often **destroy key bridges**, overpasses, and roads, **complicating efforts to transport food**, **clean water**, and **medicine** to the areas that need it.

Heavy rain

The thunderstorm activity in a hurricane produces **intense rainfall**, potentially resulting in **flooding**, **mudslides**, and **landslides**.

The **wet environment** in the aftermath of a hurricane, combined with the destruction of sanitation facilities and a warm tropical climate, can **induce epidemics of disease** which claim lives long after the storm passes.

Storm surge

Storm surge is the **abnormal rise in seawater level** during a storm or a hurricane.

The surge is caused primarily by a **storm's winds pushing water onshore** and to lesser extent low pressure associated with intense storms. The severity of a storm surge is affected by intensity, size and speed of the storm and the type of the coast.

Climate change

23 September 2019

Definition

Climate change is a **large-scale**, **long-term** shift in the planet's **weather patterns** and average temperatures.

The climate change we are experiencing currently is **due to human activity**.

Human activity is currently **generating** an excess of long-lived **greenhouse gasses** that – unlike water vapour – don't dissipate in response to temperature increases, resulting in a continuing build-up of heat.

Key greenhouse gasses include **carbon dioxide**, **methane** and **nitrous oxide**.

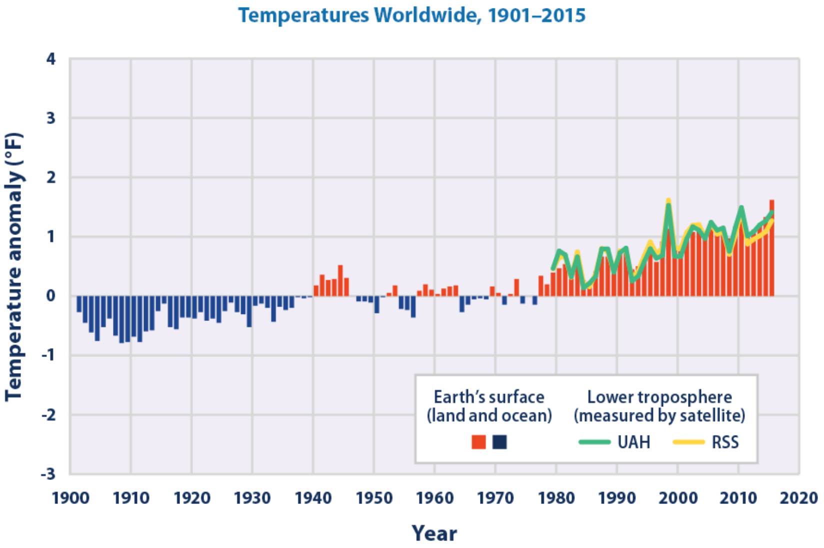
Global Temperature

Warm air holds more water vapour than cold air.

The rising air temperatures since the 1970s (see the graph on the right) have caused the atmospheric water vapour content to rise as well.

This **increased moisture** provides **additional fuel for hurricanes**.

Climate models project an increase in the average precipitation rate of hurricanes as a result of global warming.



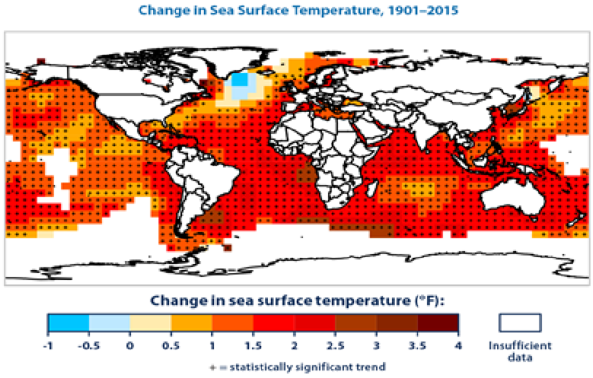
Data source: NOAA (National Oceanic and Atmospheric Administration). 2016. National Centers for Environmental Information. Accessed February 2016. www.ncei.noaa.gov.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Source: https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-temperature

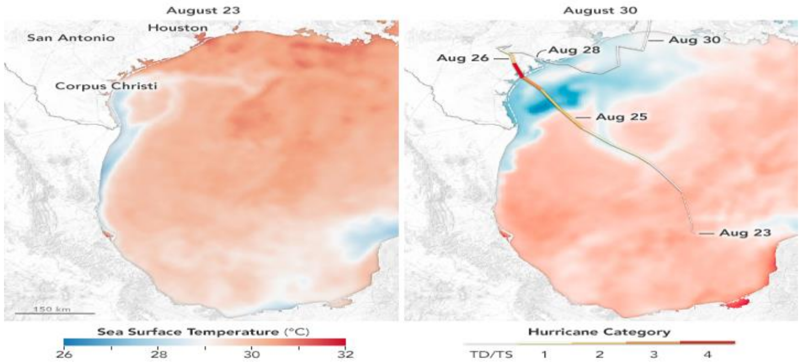
Sea Surface Temperature

As **sea surface temperature rises**, there is also less cold, subsurface ocean water to serve as a braking mechanism for hurricanes. When strong storm winds churn up cold subsurface water, the cooler waters can serve to weaken the storm.



If deeper waters become too warm, this natural braking mechanism weakens.

For example, **Hurricane Harvey intensified significantly** over deep pools of warm water in the Gulf of Mexico.



Source: https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature
https://earthobservatory.nasa.gov/images/90883/harvey-churned-up-and-cooled-down-the-gulf

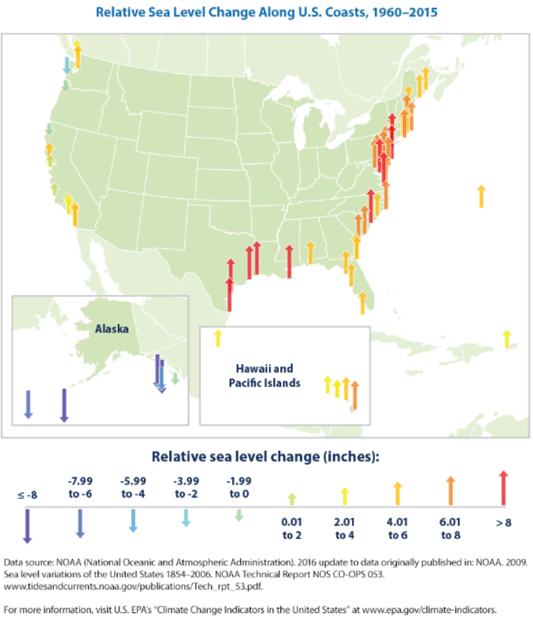
Sea Level

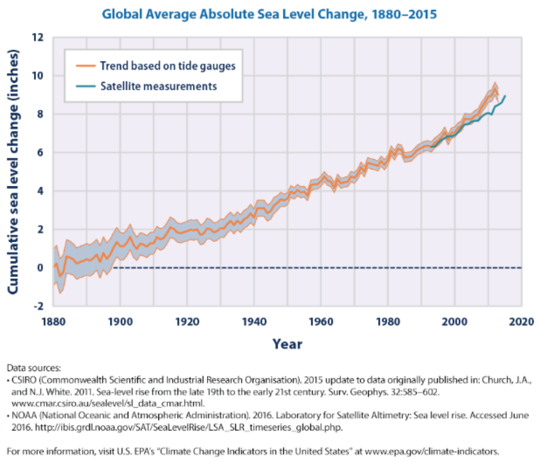
As the Global Temperature and the Sea Surface Temperature changes, so does sea level.

Temperature and sea level are linked for two main reasons:

- Warming air and oceans melt the glaciers and increase the volume of water in the ocean;

- As water warms, it expands slightly.



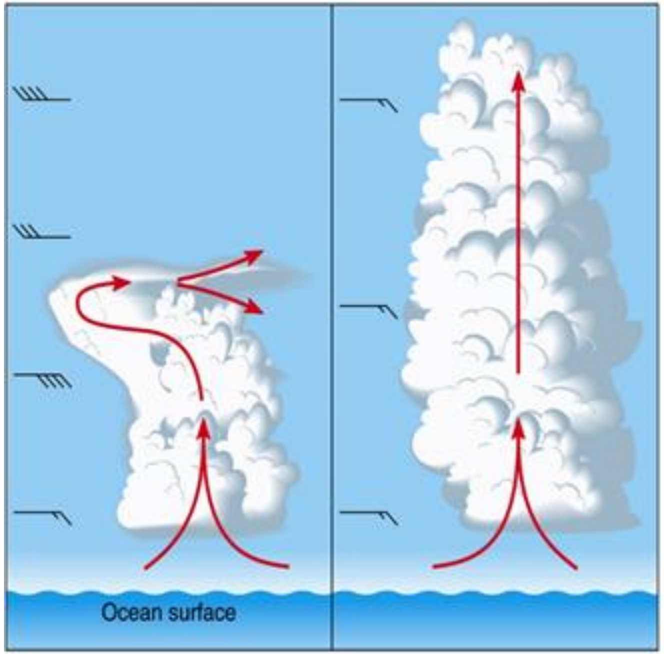


Increase in the sea level in the areas exposed to hurricanes, **increases the frequency and severity of storm surges** during hurricane landfall.

Source: https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature
https://earthobservatory.nasa.gov/images/90883/harvey-churned-up-and-cooled-down-the-gulf

Wind Shear

- Another effect that the climate change has on the weather systems is the change in **wind shear**.
- High vertical wind shear leads to **disruption of the hurricanes' formation process**.
- As temperatures around the globe become more extreme, the local winds on lower altitudes and jet streams present on higher altitudes change, often leading to an increase in vertical wind shear.
- However, currently the scientific papers are **divided on whether there is an increase or decrease in vertical wind shear**. The effects often differ by region.



Source: https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-temperature

Secondary perils

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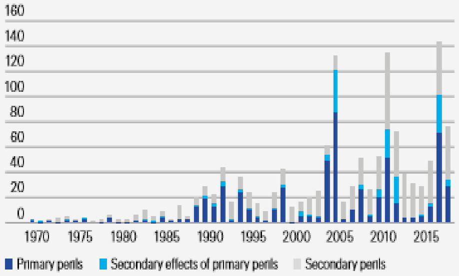
Non modelled perils

- The ABI define 4 main categories for the categorisation of Non Modelled risks. These are:
  - Regions and perils not covered by catastrophe models;
  - Secondary perils and effects not covered by catastrophe models;
  - Classes and lines of business not covered by catastrophe models;
  - Coverages not covered by catastrophe models.
- In this section, we will focus on secondary perils and effects not covered by catastrophe models.
- Examples of secondary perils in recent history:
  - Hurricane Katrina (2005): Levee failure, extreme loss amplification of super cat, flood losses.
  - Hurricane Ike (2008): Inland flooding.
  - Super storm Sandy (2012): Government intervention in application of deductibles, fire following flood.

Non modelled perils

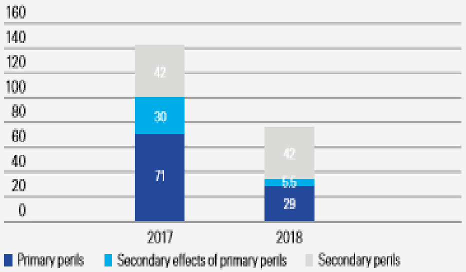
- In particular, there has been a focus on secondary effect perils in the context of US Hurricanes after the 2017 and 2018 US Hurricane seasons: Hurricane Harvey (2017) and Hurricane Florence (2018) were two of the 10 wettest storms ever to make landfall in the US.
- Scientists from the Climate and Ecosystem Sciences Division at Berkeley Lab calculate that recent hurricanes have 10-30% more rainfall than similar storms in pre-industrial times.
- A recent study by Swiss Re found that the proportion of insured losses resulting from secondary effect perils has shown an increasing trend over time.

Figure 6
Split of primary and secondary peril insured losses since 1970 (USD billion, in 2018 prices)



Source: Swiss Re Institute

Figure 7
Split of primary, secondary and secondary-effect natural catastrophe insured losses in 2017 and 2018 (USD billion, in 2018 prices)



Source: Swiss Re Institute

Relevance

Secondary effect perils are projected to become more relevant. Reasons for this are:

- **Global warming and rainfall**: as global temperatures increase, this increases the air's capacity to hold water, therefore causing the intensity of rainfall with any hurricane to increase. According to the Clausius-Clapeyron equation, every 1ºC increase in the air temperature increases the water holding capacity of the air by 7%.
- **Global warming and storm surge**: as global temperatures increase, this causes the expansion of water and melting of ice caps, which make any impacts of storm surge all the more devastating.
- **Rapid and increasing urbanisation of coastal regions**: higher concentrations of population and assets in exposed areas again results in the impact of such perils.
- According to an article published last year in Nature (vol 558, James Kossin) showed that the land speed of cyclones between 1940 and 2016 has gone down 16% for North American hurricanes. Clearly, the longer that the hurricane spends in one place, the more rain that can fall in that area.

Challenges in Quantifying Risks

However, secondary effect perils are difficult to model:

- They usually affect extremely localised areas.
- The data for calibrating models is extremely limited – modelling of floods requires extremely accurate geo-location resolution, where one or two feet of difference in elevation can make a big difference. This data was not historically captured.
- The dependencies between secondary effect perils and with primary perils is difficult to capture with any certainty.
- They are sometimes affected by the human response to the primary peril.
- Additionally, modelling of these perils is not as mature as it is for primary perils, and will take time to accumulate the data and calibration for reliable modelling.

Hurricane Clustering

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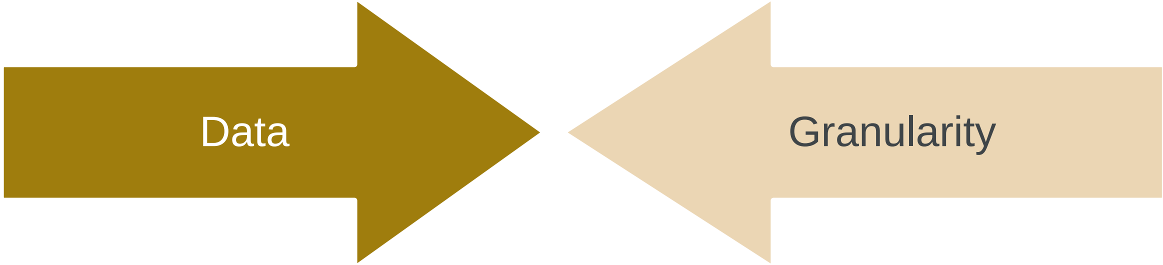
Why does it matter?

- Started to be seriously considered from approximately 2004/2005
- 2017/2018 hurricane season as reignited interest
- Interesting pieces of research – tying back to an insurance perspective
- **What do we define as a hurricane for the purposes of clustering?**



Piecing ideas together…

Category 3+

Annual number of landfall hurricanes

→ Spatial

→ Temporal

Number of hurricanes per time period?	**Hurricane occurrence based on previous hurricanes?**

- In a year
- In a month
- Over a 1 or 2 week period
- Over a ‘standard’ hurricane season

- Waiting time between hurricanes
- Hurricane occurring within 2 weeks of a previous event
- Average waiting time between hurricanes during hurricane season

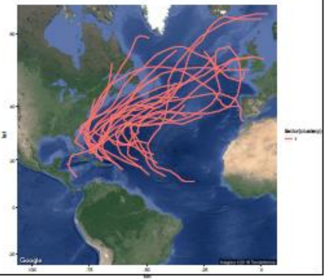
Spatial Clustering

Group 1

Further from the Equator,

usually not very strong,

curve up, few landfalls

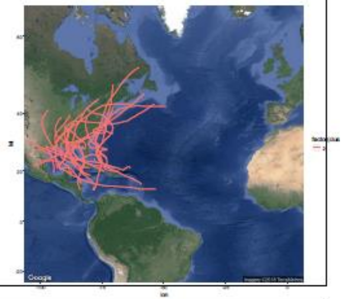


Group 2

In the Gulf , hurricanes do not have time to gather energy

High probability of landfall

Example: Katrina



Group 3

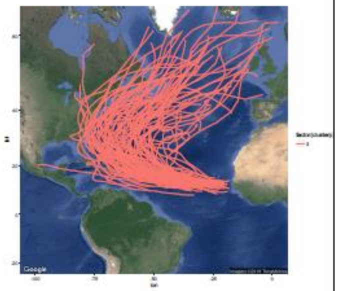
East Atlantic,

near the equator,

time to gather energy,

curve up

Example: Hugo, Florence



Group 4

Near the equator

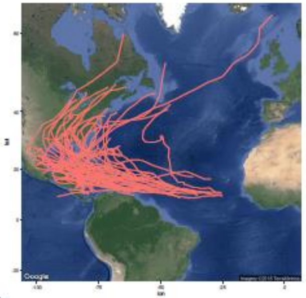
More to the west

straight paths

towards Florida and

the Gulf

Example: Andrew, Irma, Maria



Source:
https://www.casact.org/community/affiliates/cae/0718/Papachristou.pdf
https://bankunderground.co.uk/2018/05/22/us-hurricane-clustering-a-new-reality/

Implications of the observed trends in frequency

- Choice of model parameters
- Choice of Stress Tests
- Communication of uncertainty
- Validation
- Should we aim for more integration of climate models with statistical models?
- Risk management
- Reinsurance cover and pricing
- Operational preparedness
- Other implications: storm surge and flooding

Exploratory analysis of historical hurricane data

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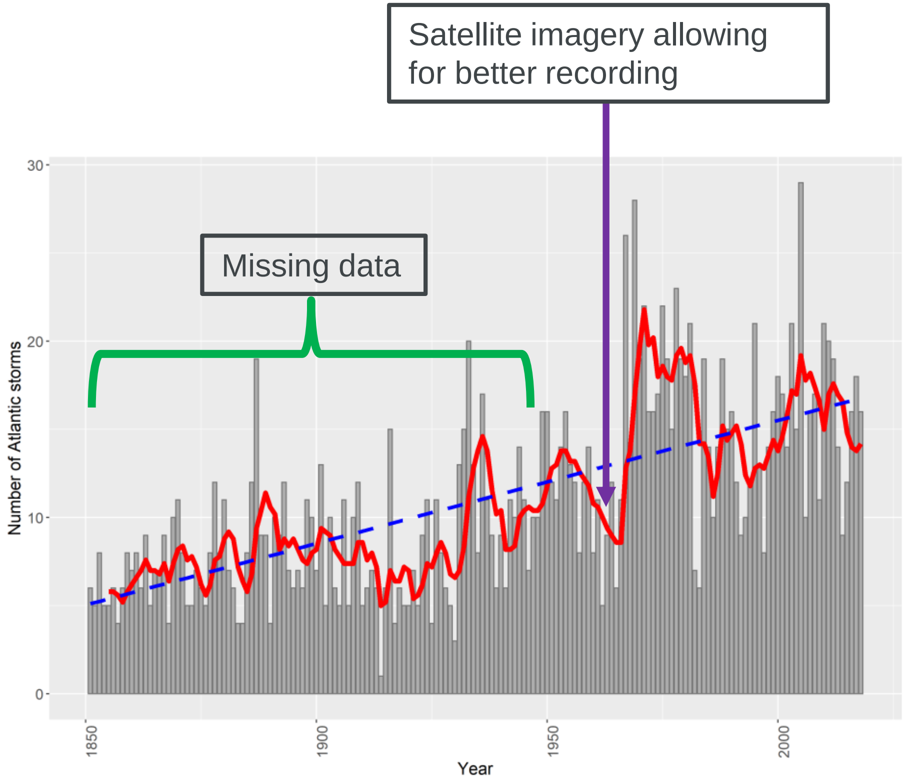
Hurricane data

- The **Hurricane Database** (**HURDAT**), managed by the National Hurricane Center, contains details of tropical cyclones that have occurred within the Atlantic Ocean and Eastern Pacific Ocean since 1851.
- Information contained includes:
  - Specific identifier
  - Date
  - Location (latitude, longitude)
  - Status (i.e. Hurricane, Tropical Storm etc) at each point in time
  - Wind speed
  - Pressure
  - Whether the tropical storm has made landfall.
- **The following analysis is performed in R using the HURDAT package.**

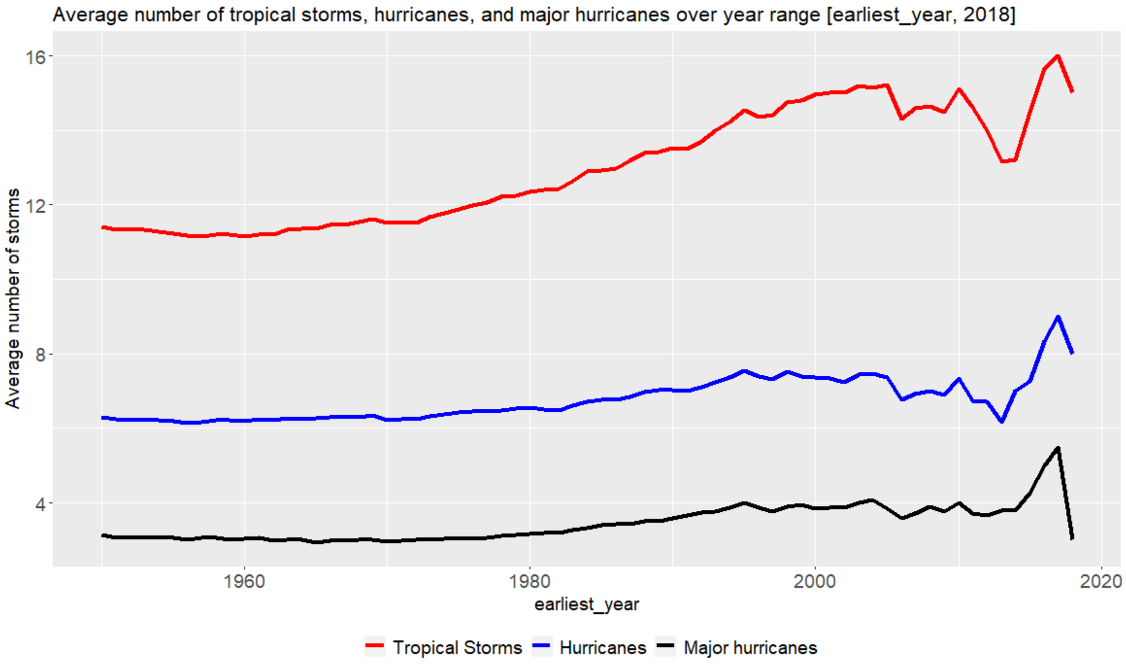
Data issues

The increase in the number of storms is likely due to be:

- to **missing data** in the early years combined with,
- **better technology to record storms**, increasing their number.



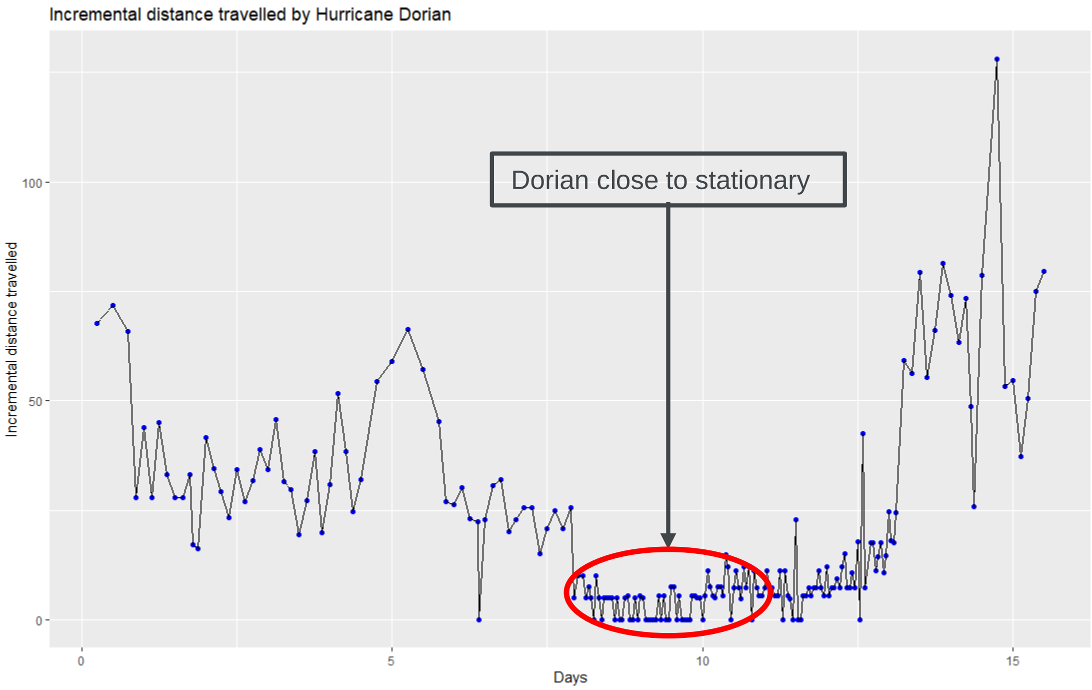
Storms frequency and intensity



- Between 1960 and 2018, there has been an annual average number of around **11.1 tropical storms** with about **6.2** becoming **hurricanes**, and **3.0** becoming major hurricanes.
- Between 2000 and 2018, there has been an annual average number of around **14.9 tropical storms** with about **7.4** becoming **hurricanes**, and **3.8** becoming major hurricanes.
- This **increase in frequency** is correlated with the rise in North Atlantic **sea surface temperatures**.
- The **strongest hurricanes have also increased in intensity** according to a paper published in the journal Nature.

https://www.ssec.wisc.edu/~kossin/articles/nature07234.pdf

Hurricane speed



Why is this important?

Slower speed means:

- more rain
- a longer period of hurricane-force winds

⇒ **More destruction**

Is slow hurricane speed specific to Dorian?

A 2018 published article (*James P.Kossin* **volume 558**, pages104–107 (2018)) in the journal Nature has shown that:

- Over the past 70 years the speed of hurricanes and tropical storms has slowed about 10% on average.
- Over land in the North Atlantic and Western North Pacific specifically, storms are moving 20% to 30% more slowly.

Should long-term hurricane speed assumptions be included in cat models?

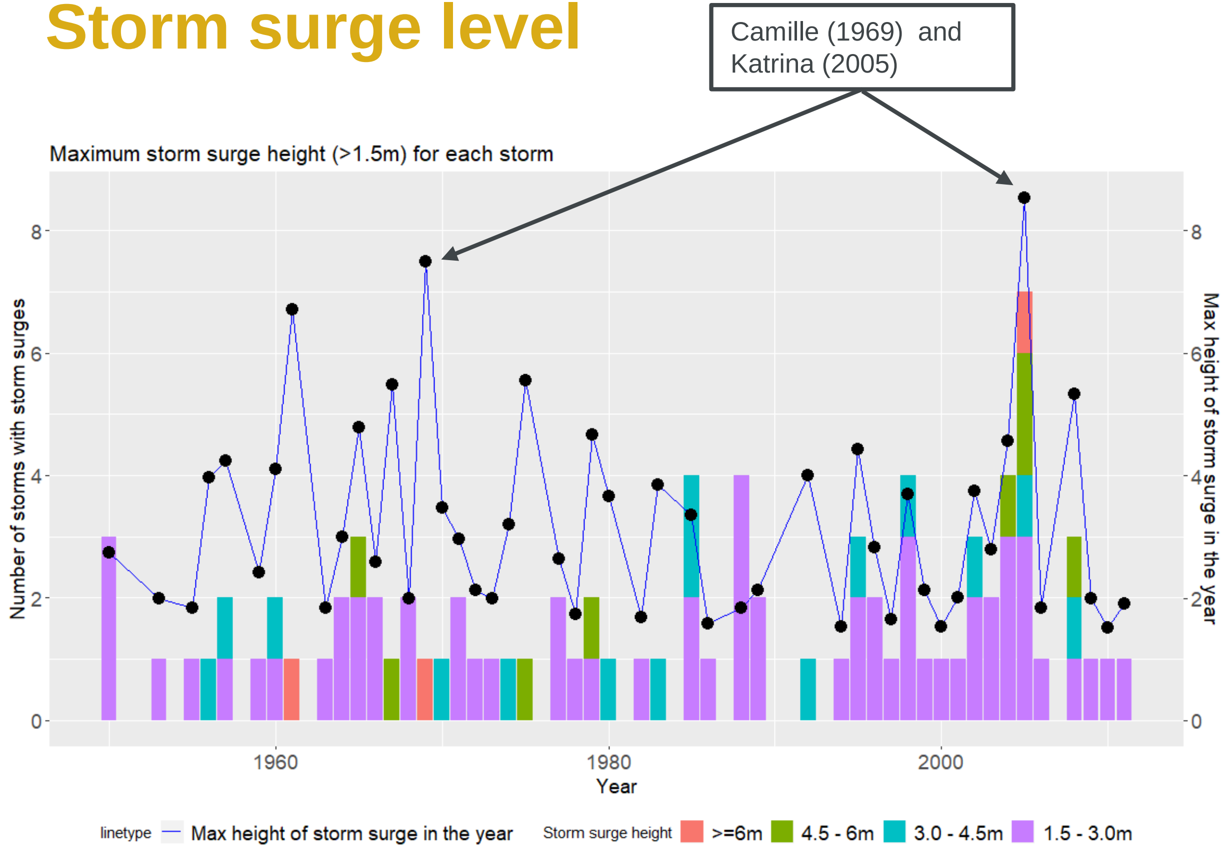
Next steps: do our own analysis based on hurdat data to check whether past hurricanes share that behaviour.

The data used to create this graph comes from: https://www.wunderground.com/hurricane/atlantic/2019/tropical-storm-Dorian

Storm surge data

- The **Storm Surge Database** (**SURGEDAT**) compiles from various sources details on storm surge events since 1880.
- Information contained include, for a given storm and year:
  - Peak surge (meters and feet)
  - Location
- Similarly to the HURDAT dataset, the earlier years are not reliable.

Storm surge level



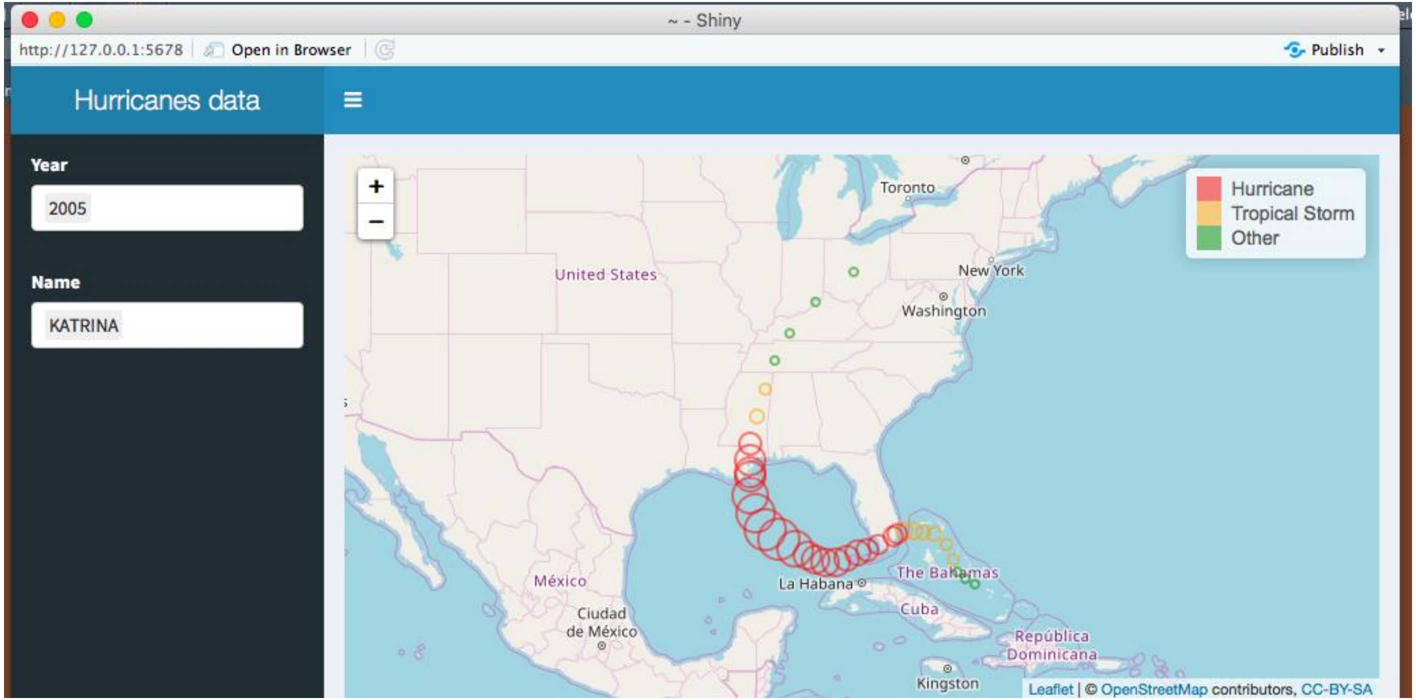
Why is this important?

As global temperatures increase, this causes the expansion of water and melting of ice caps, raising average sea levels and making the impact of storm surges more devastating.

The graph only shows the maximum level of storm surge for a given storm. However, some storms create several storm surges as they move along, causing a large amount of destruction.

Next steps: investigate further based on surgedat whether storm surge are getting worse, more frequent.

R shiny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Hurricanes data
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Hurricane
Tropical Storm
Other
Toronto
United States
New York
Washington
México
Ciudad de México
La Habana
The Bahamas
Cuba
República Dominicana
Kingston
Leaflet | © OpenStreetMap contributors, CC-BY-SA

Next steps on analysis

- More analysis to be performed:
  - additional analysis on the HURDAT and SURGEDAT data (e.g. signs of clustering, hurricane slowing down?)
  - Increase the data pool by looking for additional publicly available datasets such datasets on rainfall.
  - develop further the R shiny app with all that the data above to produce informative visualisation


Market response
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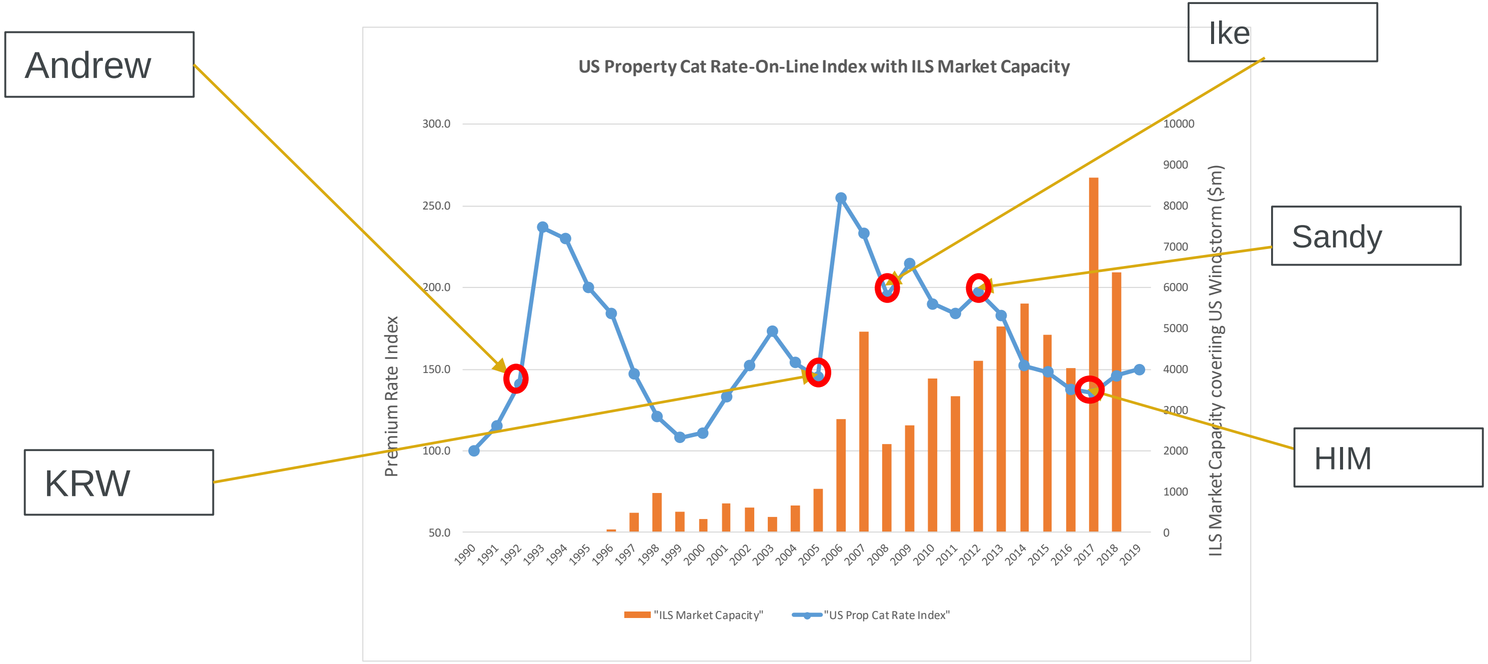
US Property Cat Rate Index and ILS Capacity



Hurricane Andrew in 1992 and 2005 events were major market-moving events.

Ike in 2008 also notable impact.

Rates still fell after Sandy in 2012 (although probably slowed the decline).

Record HIM year didn’t move rates much.

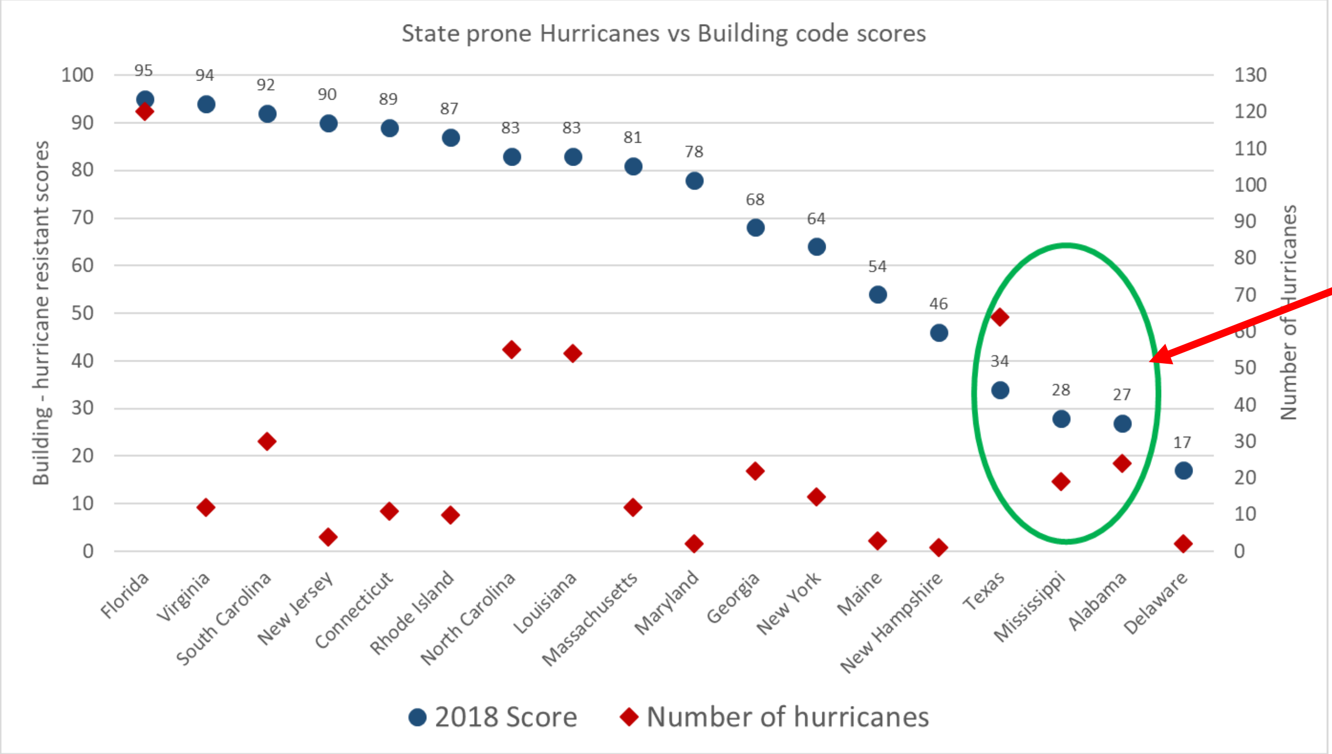
Non-hurricane Prop Cat events will have had an impact on rates (WTC, 2010/11 earthquakes)

Building codes

- The Insurance Institute for Business & Home Safety (IBHS) conducted an analysis, evaluation, and comparison of regulations and processes governing residential building construction in the 18 states most vulnerable to catastrophic hurricanes along the Atlantic Coast and Gulf of Mexico.
- The building score is derived by taking into consideration:
  - Adoption and enforcement of building codes;
  - Code official and certification and training;
  - On-site implementation, as measured by contractor and subcontractor licensing

State	2012 Score	2015 Score	2018 Score
Florida	95	94	95
Virginia	95	95	94
South Carolina	84	92	92
New Jersey	93	89	90
Connecticut	81	88	89
Rhode Island	78	87	87
North Carolina	81	84	83
Louisiana	73	82	83
Massachusetts	87	79	81
Maryland	73	78	78
Georgia	66	69	68
New York	60	56	64
Maine	64	55	54
New Hampshire	49	48	46
Texas	18	36	34
Mississippi	4	28	28
Alabama	18	26	27
Delaware	17	17	17

Building Codes vs State prone hurricanes



States subject to hurricanes but with poor building codes regulations and processes

Timeline of Events and Market Developments

	Hurricane Events	Market	Modelling / Analytics	Gov't / Regualtory
1980s	1985 events	First ILWs traded	Cat Modelling Companies emerge	
1990s	1992 - Hurricane Andrew	Elminted a number of treaties Contributed to Lloyd's collapse Failure of Several domestic insurers Big increase in premium rates Start of the Bermuda Prop Cat Market Other ART solutions explored Cat Bonds Emerge	Puts Hurricane Models "on the map" Increasing focus on climate research (IPCC Assessment reports)	"Wake-up call" for goverments Prompts formation of FHCF Tougher building codes
2000s	Hurricane Ivan			
	2005 Events - KRW	Several Bermuda reinsurers put into run-off New "Class of 2005" adds capacity Notable up-tick in ILS issuance Increase in premium rates More forcus on T&Cs (flood, BI exclusions)	New Cat Model versions - generally increase to capital (RMS v6; AIR v9)	Kyoto protocol in force (primarily agreement to reduce emissions)
	2008 - Hurricane Ike	Some rate increases		Solvency II Directive Explicit Cat Risk captial for European insurers
2010s	2010/11 - fairly active			
	2012 - Storm Sandy	No increase in rates	Continued Cat model development Increases in captial, particularly re. inland exposure	US Risk-based Capital - introduces explicit Cat Risk Charge
	2017 Events - HIM	High capacity - limited impact on rates	Increasing focus on hurricane "clustering"	Paris Agreement

Future

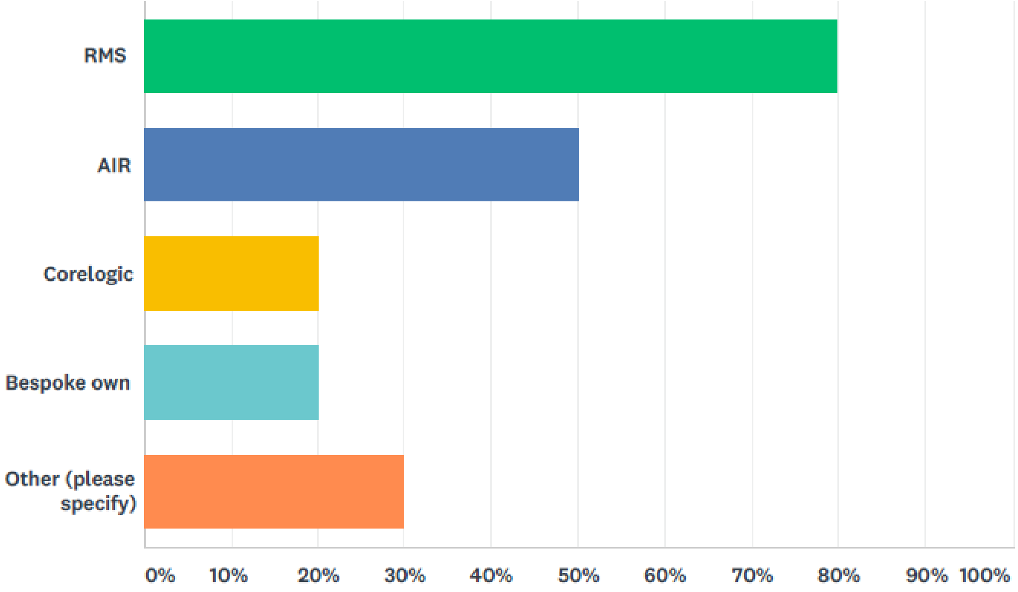
- Abundant capacity, keeping rates down (even post-2017)
- Potential for increasing hurricane activity (climate change?)
- Next iterations of cat models...capital impact?
- More alternative capital?
- Increasing pressure on state/federal programs
- Regulatory intervention

Survey

Response rate is currently quite low…

What we know so far…

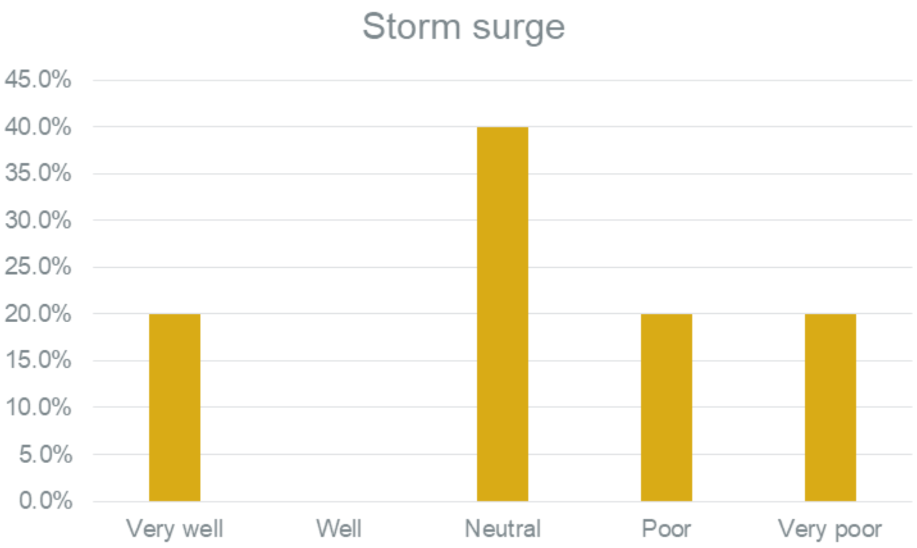
What vendor models are people using?



Survey

Some of the results so far:

How well is storm surge captured in your cat model (before on - top adjustments / judgements are applied)?

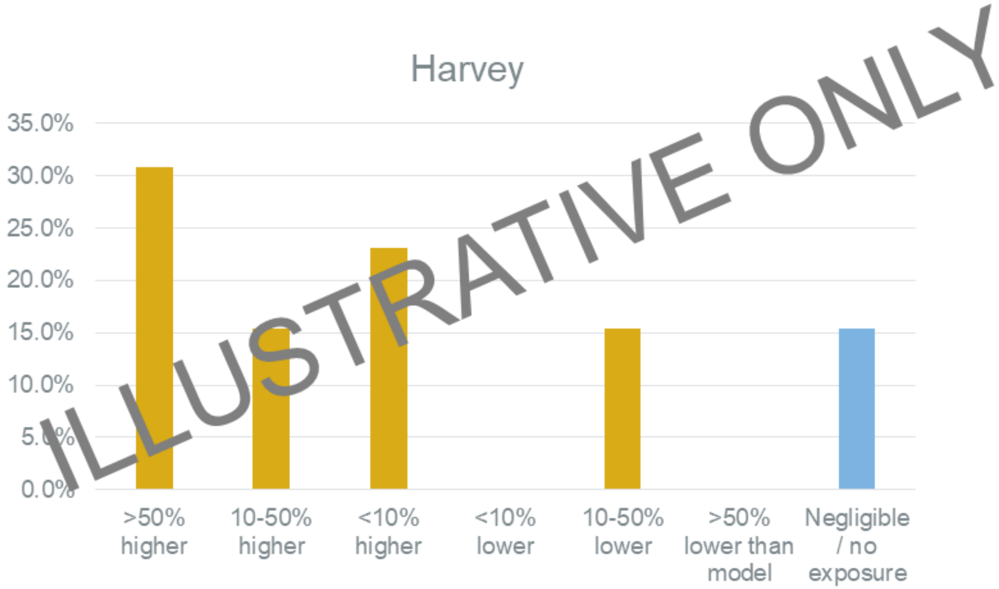


Survey

What we hope to be able to show…

How did actual experience on the 2017 US Hurricanes compare to the modelled expectation (before on - top adjustments / judgements are applied)?

What are the drivers of this difference?



Please participate!

https://www.surveymonkey.co.uk/r/GRV5RNW

Final thoughts

01 October 2019

Summary

- This is work in progress and we wanted to give you an update
- Few questions to explore:
  - Following hurricanes in 2017 and 2018, are we modelling risks adequately?
- More investigations expected to be performed:
  - **Clustering**: the type of adjustments usually made by companies
  - **Climate change**: create scenarios around climate change, interview experts, collect a variety of views from papers and analyse data (if exists and available).
  - **Analytical tool**: to be developed further to contain more information on hurricanes (e.g. losses) and add secondary perils information.
  - **Survey**: provide an analysis of the results of the survey.

Questions

Comments

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