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Chaucer

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North Atlantic Hurricane:
a pragmatic view of frequency and clustering

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North Atlantic Hurricane
What we’re going to talk about…

- Introduction; some assumptions and a basic view of risk
- Frequency and the Long Term Rate
- Clustering; of landfall hurricanes
- Climate teleconnections and a changing climate

The starting point for this discussion is:

- Property portfolio in the US
- Vendor model used
- Unadjusted
- No clustering
- LTR used as view

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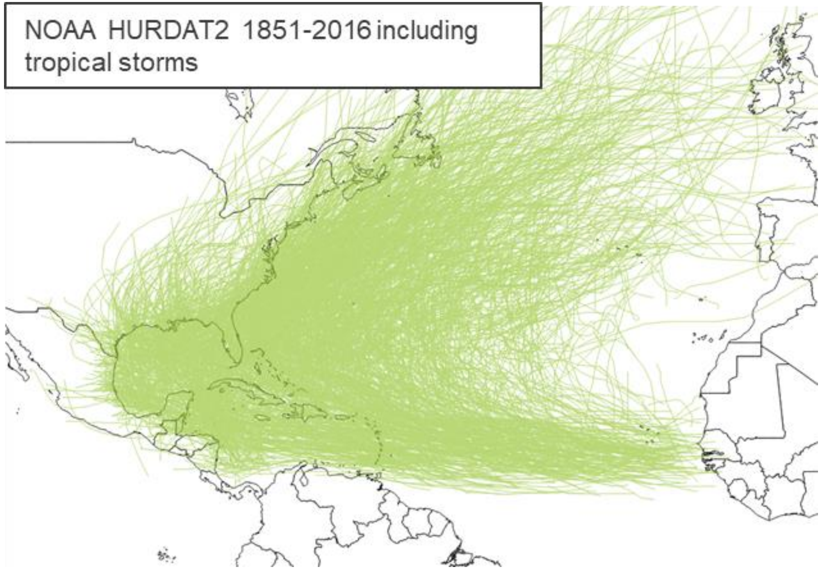
Introduction and View of Risk
Some Caveats & Assumptions

- Industry view of hurricane frequency is a long term view, starting in 1900
- Frequency focuses on landfalling events
- At landfall, only categories of Cat. 1+ are deemed significant for wind damage, assuming tropical storms and depressions are unlikely to generate insured losses that would trouble most insurers, or reinsurers
- HURDAT2 is the standard data set
- Many portfolios are dominated by U.S. wind, so focusing on landfalls in the U.S. is important
- This view of risk will focus on landfalls, and less so on basin frequency – although there is a link, any correlation is less clear



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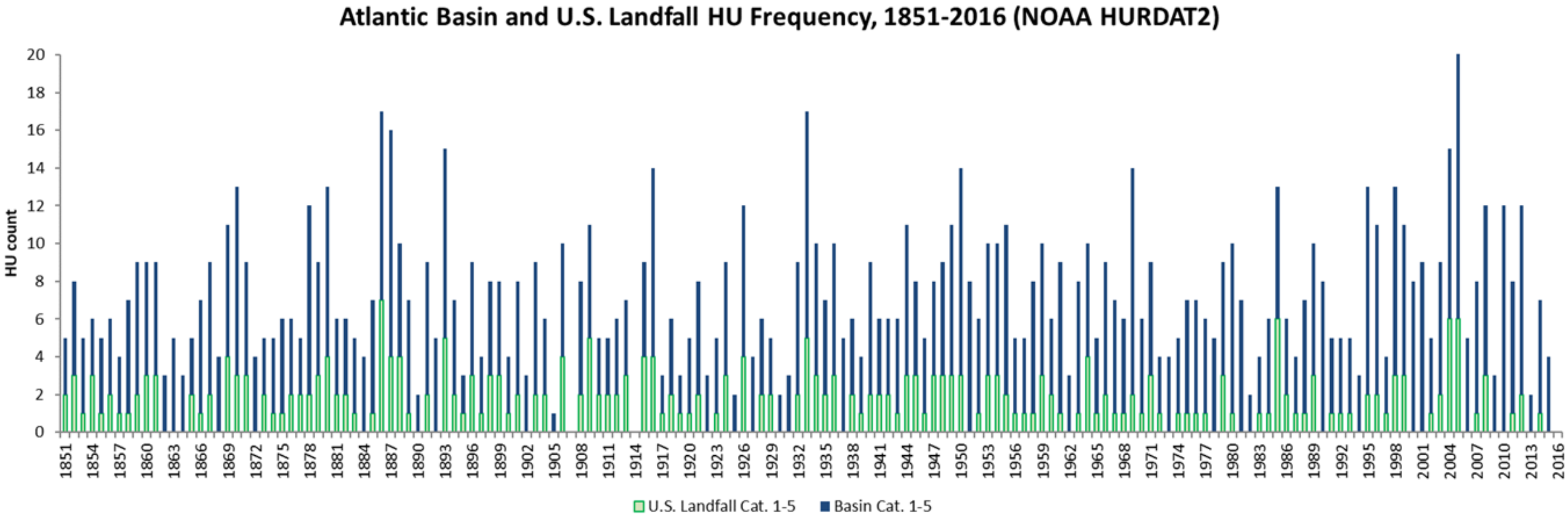
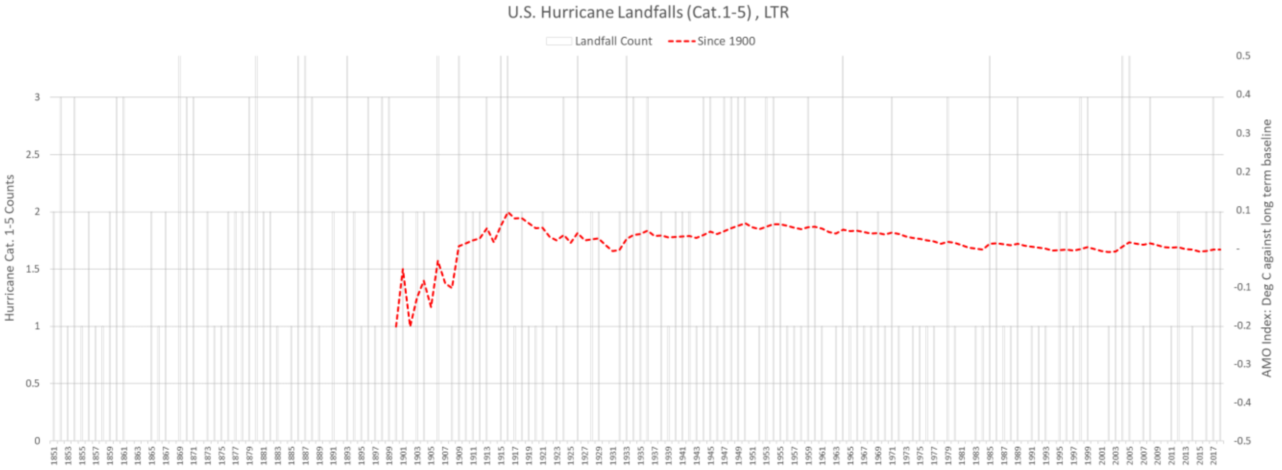
Introduction and View of Risk
The Data – Atlantic Basin v. U.S. Landfall

- The ratio between basin activity and number of landfalls is not straight forward
- It has long been assumed that these two frequencies were positively correlated, however recent research, and some trend analysis may be suggesting otherwise



Hurricane Frequency
Long Term Rates – Traditional LTR since 1900



- Traditionally 1900 is used as the historical benchmark within the data set for deriving hurricane cat. models
- It is used across the industry – with various alternative near term, or warm sea surface temperature rates being compared to the LTR

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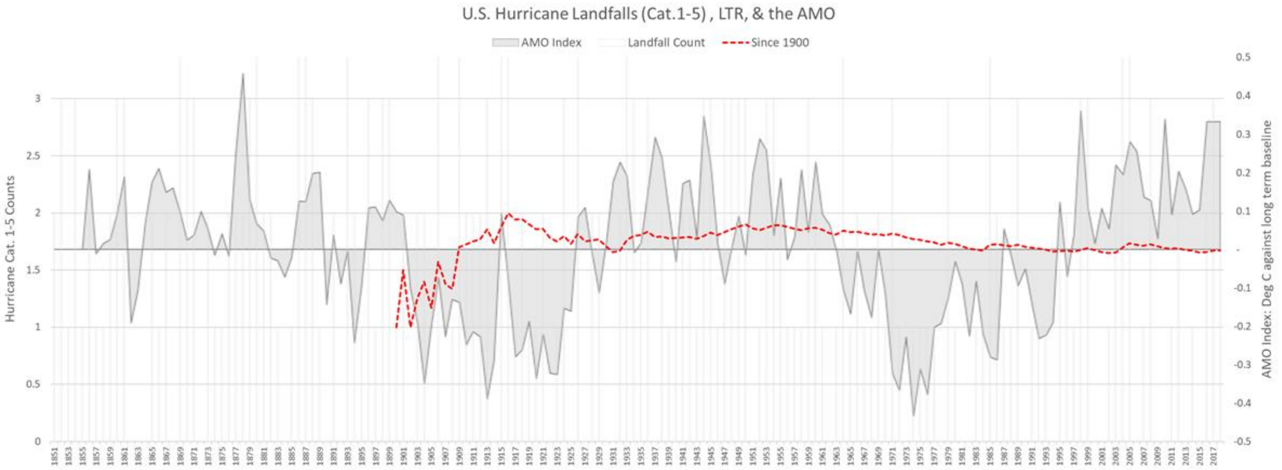
Hurricane Frequency
Long Term Rates – landfalls and the AMO



- While the AMO might be correlated to basin activity, it is seemingly less so to landfalls
- Despite two “cycles” of warm and cold since 1900 the long term rate has continued to decrease

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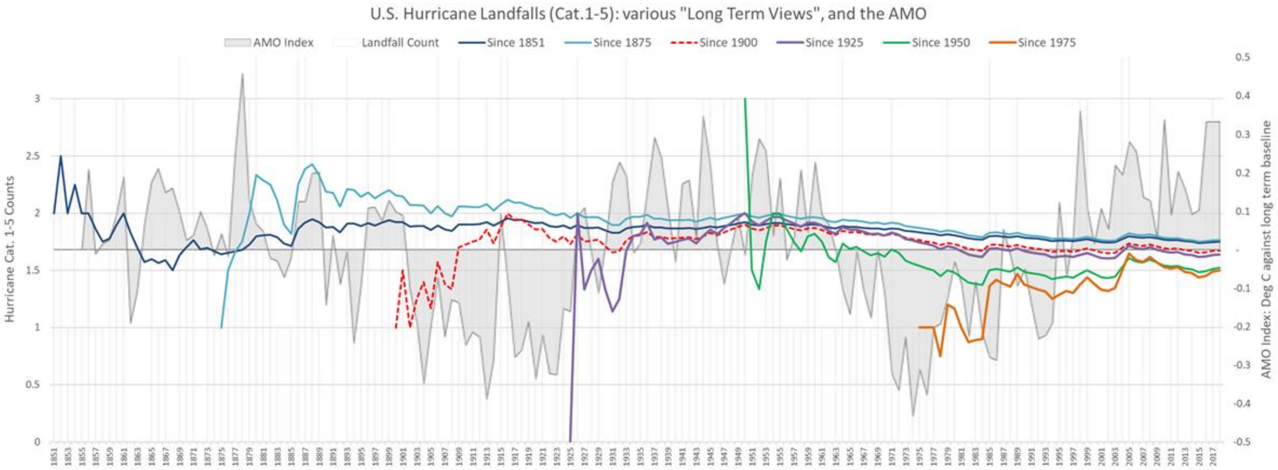
Hurricane Frequency
Long Term Rates – Is 1900 really the place to start?



LTR Start	Cat. 1-5
1851	1.75
1875	1.76
1900	1.67
1925	1.64
1950	1.52
1975	1.50

- The LTR decreases as the historical period used is shortened
- This trend appears constant despite the variations in the AMO
- Three long term variants since 1900 have a lower rate

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Hurricane Frequency
If it is a long term average, why is it not consistent?

- Category 1 and 2 hurricanes drive the decreasing trend in overall landfalls
- However, even major hurricane long term landfall rates exhibit some decrease since 1900 or earlier
- Does this indicate a bias in the early part of HURDAT?
- One possible explanation is that many smaller category storms may well have been tropical storms

LTR Start	Cat. 1-5	Cat. 1-2	Cat. 3-5
1851	1.75	1.20	0.55
1875	1.76	1.19	0.58
1900	1.67	1.11	0.56
1925	1.64	1.06	0.57
1950	1.52	0.99	0.54
1975	1.50	1.00	0.50

Decreasing

Decreasing

Flat to decreasing

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Hurricane Frequency
Should we even use historical data?

1. **Physical modelling**
2. Counterfactual / simulating historical record

- In September 2018, Kerry Emanuel from MIT presented at the London OASIS Loss Modelling conference on the question of should historical data be replaced by physical modelling…

- The proposition is to remove the reliance on historical data all together
- Given the complexities of oceanic and atmospheric patterns, and teleconnections (ENSO, NAO, AMO, AEW, etc.)…
- … and considering anthropogenic warming and other climate change effects, Emanuel suggests utilising weather simulation may be better at capturing where the hurricane landfall rate is going; rather than where it's been

Hurricane Frequency
Should we even use historical data?

1. Physical modelling
2. **Counterfactual / simulating historical record**

- Counterfactuals* demonstrates how the current historical record is only one version of what could have happened – large uncertainty and variability can be generated simply by simulating different versions of that history
  - * Based on work carried out by RMS (a catastrophe model vendor) on various extreme events, and by Richard Dixon of CatInsight on European Windstorm modelling

- However, practically many insurers are unlikely or unable to abandon historical data – nevertheless it is good to be aware of its limitations

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Hurricane Frequency
Instead, perhaps a shorter "LTR" is a compromise

- A good starting point for a view of risk on hurricanes is the average rate…
- The case for moving away from 1900:
  1. Weather satellite era (1958/9 onwards)
  2. Hurricane Hunter aircraft (post WW2)
  3. Observation bias could have led to an overstatement of Cat1-2 in pre-1950 data
  4. More weather stations in recent history
  5. More commercial boat traffic in Caribbean, Gulf, and of East Coast in latter half of 20th century
- … so, there are good reasons to start a "Long Term" view of hurricane rates around 1950, rather than 1900

What impact would this have on a portfolio of U.S. property?

RP	Made up EP (mUSD)	% Change LTR	EP with LTR View
1000	778.2	-1%	772.3
500	728.9	-2%	715.7
250	625.5	-2%	611.1
200	587.2	-3%	570.0
100	456.7	-3%	442.0
50	330.4	-4%	315.7
30	243.6	-5%	231.0
10	104.2	-8%	96.3
5	50.3	-17%	41.9
2	4.0	-25%	3.0
AAL	43.0	-8%	39.8

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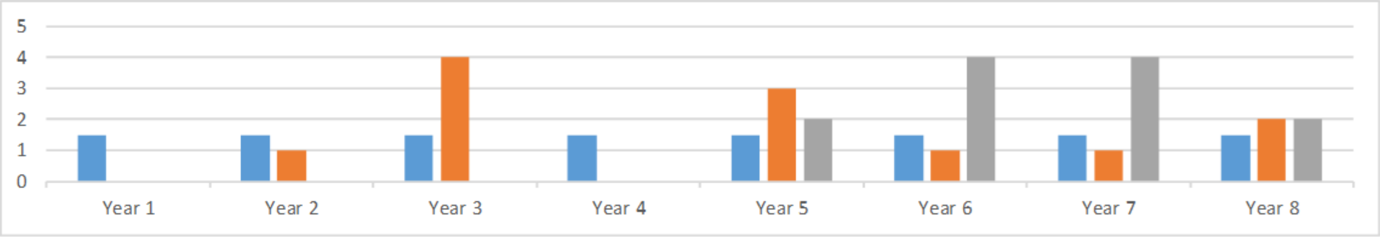
Hurricane Frequency
Long Term Rates – mini-summary

1. We are interested in basin activity, but we need to understand landfalls more
2. An LTR since 1950 rather than 1900 is likely to be based on better quality observation data
3. Changing the baseline LTR assumption from 1900 to 1950 would be a material adjustment that is anchored in a pragmatic view of historical data

Hurricane Clustering Background

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Mean Event Rate	Variance	Over-dispersion
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0	0.00
0.0	1.0	4.0	0.0	3.0	1.0	1.0	2.0	1.5	1.75	1.17
0.0	0.0	0.0	0.0	2.0	4.0	4.0	2.0	1.5	2.75	1.83



Underlying clustering is a question of **frequency**

- How many hurricanes do I expect to occur on average?
- With what pattern to I expect them to see them there?

I need to be satisfied that…

- I model as many zero landfall years as I expect
- I model as many years as I expect with 1, 2, 3, or more hurricanes
- I model the total number of hurricanes I expect

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Hurricane Clustering
Is there any significant signal?

US Landfalls Category 1 - 5									
	1950 - 2018			1950 - 1989			1990 - 2018		
Events Per Year	YearCount	Observed	Poisson	YearCount	Observed	Poisson	YearCount	Observed	Poisson
6	1	1.4%	0.3%	1	2.5%	0.4%	-	**0.0%**	0.2%
5	2	2.9%	1.3%	-	0.0%	1.5%	2	**6.9%**	1.0%
4	1	1.4%	4.4%	1	2.5%	4.9%	-	**0.0%**	3.8%
3	10	14.5%	12.1%	6	15.0%	12.9%	4	**13.8%**	11.0%
2	13	18.8%	24.8%	7	17.5%	25.3%	6	**20.7%**	23.9%
1	25	36.2%	33.9%	19	47.5%	33.2%	6	**20.7%**	34.7%
0	17	24.6%	23.1%	6	15.0%	21.8%	11	**37.9%**	25.2%
Year Count	69			40			29		
Total Event Count	101			61			40		
Average No. Events per year	**1.4638**			**1.5250**			**1.3793**		
Variance	1.7818			1.5378			2.1724		
	1.22			**1.01**			**1.58**		

Historical record compared to a Poisson distribution (typically used in modelling)

There is over-dispersion – patterns are different to a pure Poisson process

The pattern is not consistent

The pattern of very little over-dispersion pre-1990 and more since 1990 is repeated in Cat 3-5s

The most obvious signal is the number of years with no hurricanes

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Hurricane Frequency
Others agree that it exists… but is it material?

- In November 2018, Lloyd's and IFoA hosted a panel on hurricane clustering
- The majority concluded that clustering happens, and numerous statistical proofs were given for its existence
- The outstanding question is about clustering's materiality – it is likely to be portfolio specific
- For a proxy portfolio with dummy reinsurance, we find that it has a limited impact to the all perils AEP when using a vendor supplied catalogue that is part Poisson and part Negative Binomial clustering
- But implications to outwards reinsurance purchasing, and portfolio management decisions are material

All Perils AEP

RP	Gross % Change	Net % Change
1000	3%	3%
500	2%	4%
250	2%	3%
200	2%	3%
100	2%	3%
50	2%	3%
30	2%	2%
20	2%	2%
10	1%	1%
5	0%	0%
2	-1%	0%
AAL	0%	0%

North Atlantic HU AEP

RP	Gross % Change	Net % Change
1000	5%	6%
500	5%	6%
250	5%	9%
200	5%	14%
100	6%	16%
50	6%	12%
30	5%	9%
20	4%	7%
10	2%	2%
5	-2%	-2%
2	-13%	-12%
AAL	0%	0%

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Hurricane Frequency
A new LTR view + Clustering? (1 of 2)

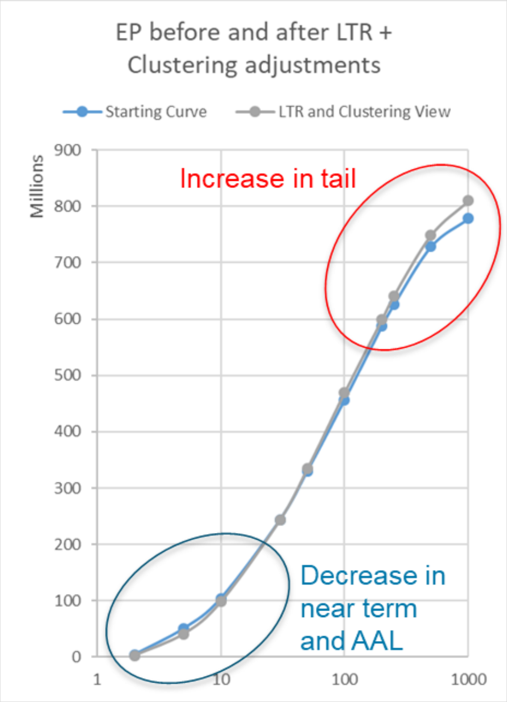
- Building on a new LTR, the Poisson/Neg. Binomial clustering is added to the gross loss, NA HU EP
- Importantly, more years of no landfalls are present in the re-simulated catalogue
- Clustering increases to the tail overcome some of the reductions with the LTR change
- The AAL is unchanged
- The near term decreases in the clustered adjustment, adding to that from the LTR change

RP	Made up EP	% Change LTR	EP with LTR View	Clustering Adjust	EP with Clustering	Overall	EP with both veiws
1000	778.2	-1%	772.3	5%	816.4	4%	810.2
500	728.9	-2%	715.7	5%	763.2	3%	749.4
250	625.5	-2%	611.1	5%	656.6	3%	641.4
200	587.2	-3%	570.0	5%	617.3	2%	599.2
100	456.7	-3%	442.0	6%	485.3	3%	469.6
50	330.4	-4%	315.7	6%	350.0	1%	334.4
30	243.6	-5%	231.0	5%	256.6	0%	243.3
10	104.2	-8%	96.3	2%	106.0	-6%	98.0
5	50.3	-17%	41.9	-2%	49.2	-19%	41.0
2	4.0	-25%	3.0	-13%	3.5	-35%	2.6
AAL	43.0	-8%	39.8	0%	43.2	-7%	39.9

Hurricane Frequency
Others agree that it exists… but is it material?

- The combined view proposes a material change to a U.S. property portfolio

- The tail increases as a result of years with more landfalling hurricanes



- The near term decreases due to the addition of more zero years in the catalogue, and because of the shift to a more recent LTR

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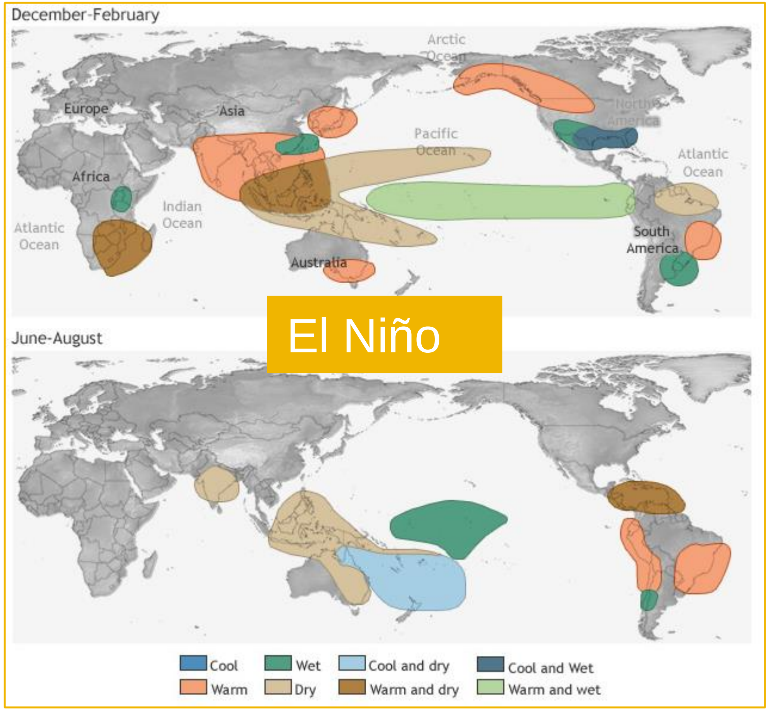
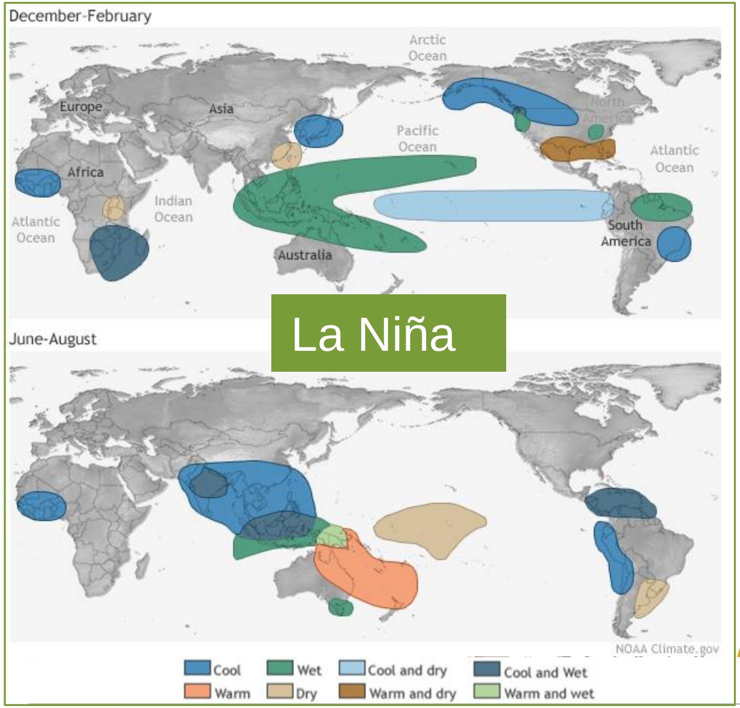
Hurricane View
Clustering and Combined Summary

1. Both the LTR and the clustering view are based on data
2. More recent, and more accurate historical data is allowed to dominate the adjustment
3. Alternative versions of this should be carried out with adjustments targeting Cat 1-2s only, for instance, or a clustered view for major hurricanes only

4. What about other climate considerations? Teleconnections? Climate change signals?

El Niño & the Southern Oscillation Complicated…





ENSO directly influences:

- Temperature
- Precipitation
- Convection

Resulting in more, or less:

- Flooding
- Drought
- Tropical Cyclones
- Wildfire

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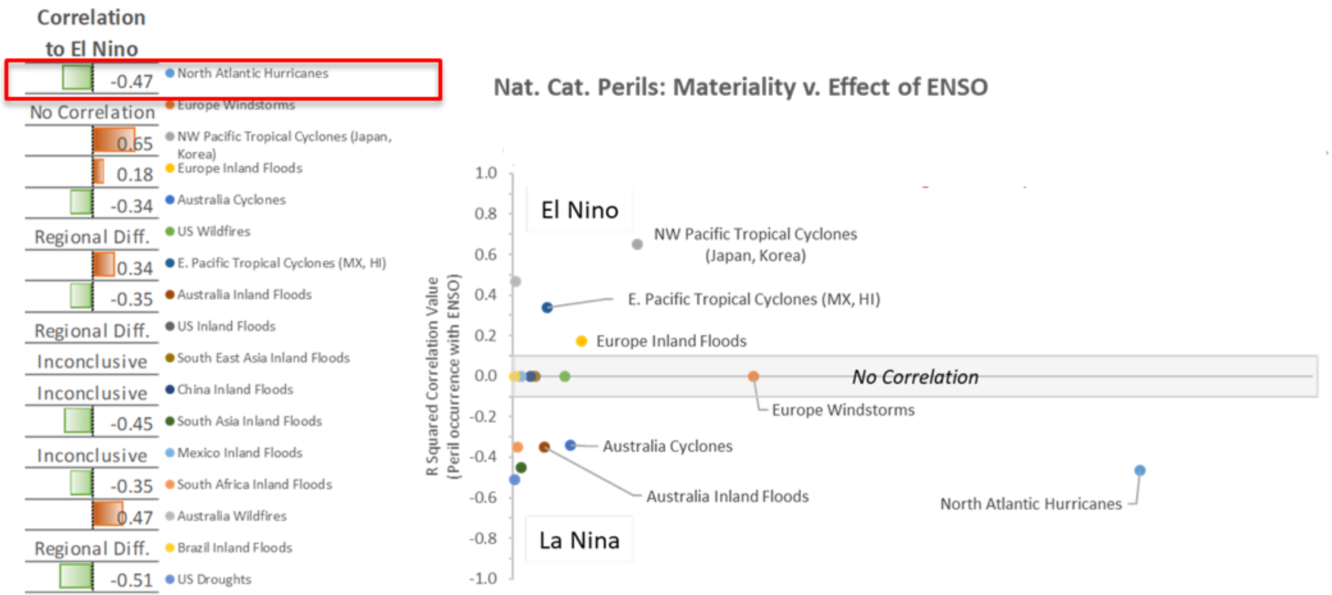
Hurricanes & ENSO
Conditioning of the LTR, or a new forecast view?



- One of the strongest correlations of any peril with ENSO is the negative correlation of Tropical Cyclones in the North Atlantic with El Niño – due to increased wind shear
- An important consideration on an annual and intra annual time scale
- Looking into ways to apply an increased or decreased probability given a forecast for a strong El Niño OR La Niña

Based on a literature review published in 2018 by Steptoe, et al (UK Met Office)

Conclusions
What's the point of all this?

1. Clearly it is possible for a company to adjust their view with these options, but there are limitations of what can be achieved

2. This is a high material peril, and due to the limited options available in most commercial cat. models it can be argued there is justification for adjustment

3. Modern hurricane cat. models could have options related to what has been discussed here:
4. 1950 and other LTR variants
5. Various clustering options (high over-dispersion for instance – 1980s to now)
6. ENSO conditioned rate sets (other teleconnections)
7. Climate change – history free sensitivity testing

Conclusions
What's next?

1. Furthermore, additional research could focus on:

2. Hurricane landfall frequency and whether it has changed, or is changing, and how best to represent frequency for modelling (re)insurance
3. The mechanisms that drive differences in landfall observations that can be reflected in our models
4. SSTs and rising sea levels regional impacts

5. From the Chaucer perspective, we are working through further sensitivity on regional variations, and trends by category of storm… and in discussion with others in the market about ENSO, and climate variability

North Atlantic Hurricane
Contacts – Questions & References

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