# UNCERTAINTY IN HURRICANE FREQUENCY: HOW MODELERS APPROACH THE PROBLEM

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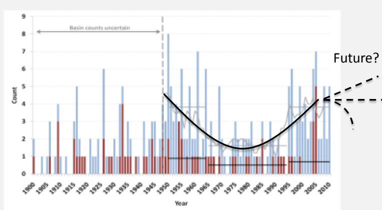
## PROBLEM STATEMENT

Are historical average frequencies adequate for describing future risk?

**Hurricane Frequency Isn't Stable Over Time**



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## DECISION MAKING TIME-SCALES

| Forecast | Period | Issues and Applicability |
|---|---|---|
| Short-term (seasonal) | < 1 year | Volatile<br>Near-term hedging |
| Medium-term | 5 years | Relatively Stable<br>Capital Planning<br>Relationship Structuring Risk Transfer Strategies |
| Long-term (climate) | 50+ years | Uncertain<br>Engineering and development planning |



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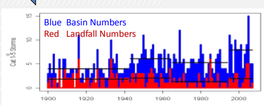
## MODELING TIME-SCALES

Historical Period

Prediction Period




Short-term Prediction <1 year

Medium-term Prediction 5-years

Long-term Prediction ~50 years

Historical Average
1900-NOW

?

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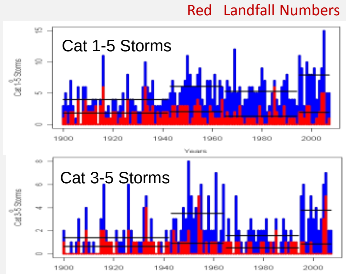
## PAST HURRICANE ACTIVITY

Blue Basin Numbers
Red Landfall Numbers

- **Atlantic basin**
  - The number of hurricanes has gone through a cycle of high – low – high frequency.
  - We are currently in a phase of high frequency.
  - The proportion of the most intense hurricanes has increased since 1970.
- **U.S. landfall**
  - There are less data on landfalling storms.
  - Therefore it is more difficult to see signals in landfalling numbers.




HURDAT data *Jarrell et al. (1992)*

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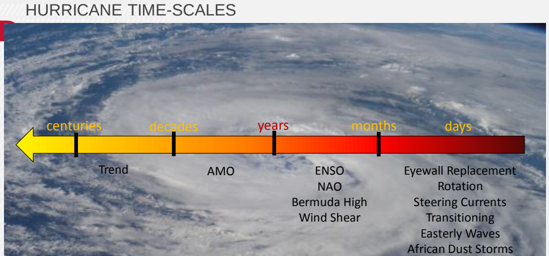
## HURRICANE TIME-SCALES




Hurricane Epsilon viewed from the International Space Station; 2005

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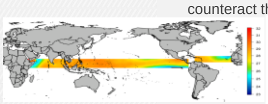
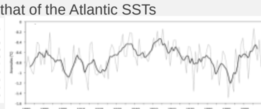
## MECHANISMS DRIVING INCREASED ACTIVITY

- Increased Atlantic SSTs increase hurricane frequency and intensity
- Conversely, a warmer Pacific Ocean acts to inhibit hurricane activity, through two principal mechanisms:
  - Increased wind shear in the Atlantic
  - Increasing atmospheric stability which suppresses convection associated with hurricanes
- Overall impact is increased hurricane activity and intensity – as the Pacific influence does not fully counteract that of the Atlantic SSTs



*Hadley Centre average July-September sea-surface temperatures from 1950-2009 the Indo-Pacific and Atlantic Main Development Region SST Regions*



*MDR – Indo-Pacific SST from 1880-2009 (grey line) and the 5-year running-mean (black line).*



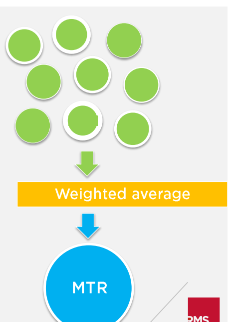

## HOW DO WE APPROACH THE PROBLEM?

- There are many theories
  - All theories are reasonable
  - All theories are consistent with the data
  - They contradict each other
  - Only time will tell which is right, and maybe none are completely right
- How do we use this spread of opinion to develop a meaningful forecast that can be used to help understand risk?

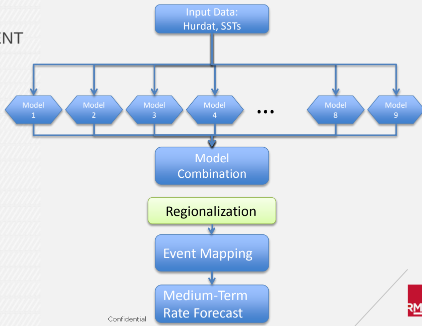


## 9 INDIVIDUAL FORECAST MODELS

Reflecting range of scientific opinion



## DEVELOPMENT SCHEMATIC






## FORECAST MODELS

| Models |
|---|
| Long-Term Average |
| Direct Hurricane Shift |
| Indirect Hurricane Shift |
| Direct MDR SST |
| Indirect MDR SST |
| Direct MDR+IP SST |
| Indirect MDR+IP SST |
| Direct MDR+IP Shift |
| Indirect MDR+IP Shift |
| Final Rates |

- Direct – direct estimate of landfall rates
- Indirect – estimate of basin rates converted to landfalls
- MDR – Main Development Region in the Atlantic
- IP – Indo-Pacific
- Shift – accounts for probability of shifting from current increased temperature phase to lowered temperatures

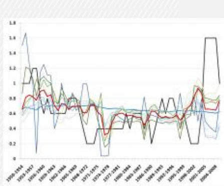


## MODEL COMBINATION

**Best Historical Model Methodology**

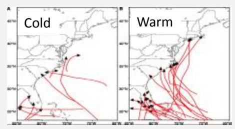
Models are combined, based on their historical skill at predicting U.S. landfalling rates

- Weighting models - for each historical 5-year period from 1950 to 2010
- Each model makes a prediction for that period
- Out of sample estimate not using information for that prediction period (e.g. SST)
- Model with the best prediction given a point
- Points added up and normalized to produce weights for each model

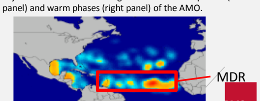


## REGIONALIZATION – GEOGRAPHIC DISTRIBUTION

- Changes in SSTs change geographical patterns of activity as well as the overall activity rates
- This shift has been seen in the observations: post-1995 storms tend to form further to the east, e.g. hurricane Julia in 2010 set the record for the most intense storm the furthest east in the Atlantic Basin.
- Atlantic Florida is particularly vulnerable to MDR-origin storms, though not as much as the Caribbean.




Tracks of major US east coast landfalling hurricanes in cold phases (left panel) and warm phases (right panel) of the AMO.

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## THE MTR RESEARCH PROCESS

There is a scientific consensus on the physical mechanism driving increased hurricane activity - but some aspects of the science remain uncertain

We aim to continually improve our MTR forecast by...

- Identifying research topics of interest / importance
- Identifying any new sources of data
- Performing our own investigation and / or working with the academic community

We test our models' forecasting skill by its performance against history

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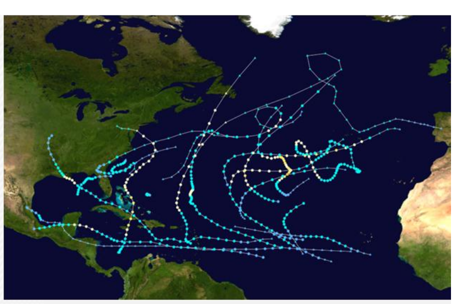
## A KEY QUESTION

Recent years
- High levels of activity in basin
- Relatively few landfalls



Scientific debate - "luck" or unknown physical drivers?

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Recent quiet landfalling years → Why?

New RMS Study + forecasting improvements → Millions of simulations under different SST regimes

New Forecast → Lower for NFL, SE, Mid-ATL less impact S FL, TX, Gulf + NEast

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## HEADLINES OF THE 2013 MTR CHANGES

- **Accounting for new scientific theories – Adding four new rate models to the forecast, providing 'non-static' landfall proportions for indirect models**
- **Improving forecasting techniques – Changing our event classification and forecasts for category 1-2 storms**
- **Updating input data – Including three additional years of hurricane counts and SSTs**
- **More insights into regionalization – Each forecast now has a tailored regionalization of rates and a more granular event mapping process**

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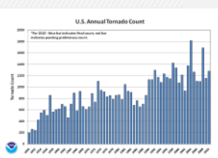
## IS CLIMATE CHANGE A FACTOR IN SCS RISK?




The effect of climate change on storms is difficult to discern for two reasons:

- Historical record is not well resolved
- Favorable SCS conditions are more tied to geography

Storms to this point have not been proven to be more violent or more intense

- EF4 and 5 tornado frequencies haven't increased over time
- EF0 and 1 tornadoes have seen increases, but most likely from historical underreporting than from any physical mechanism

Your perception of the influence of climate change depends on how you trend historical data

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## IS CLIMATE CHANGE A FACTOR IN SCS RISK?


It is unclear how a warming climate will influence SCS behavior

- Increase in warm, moist air should increase thunderstorms
- Decrease in wind shear due to decrease in temperature gradient from equator to poles should lead to a decrease in hail and tornadoes
- Strength and location of forcing mechanisms may lead to increases/drops in activity regionally

Human Impacts

- Outbreaks and severe weather peak months may shift to be earlier in the year
- More people in harms way, as winter tornadoes tend to be more fatal



## SUMMARY

- **Catastrophe models are designed to reflect risk over a medium-term (~5 year ) time horizon**
- **Understanding the effects of climate variability is key to managing catastrophe risk**
- **Tools are already available for understanding climate variability on hurricanes**
- **Understanding the impact of climate on SCS, winter storms, and floods still a work in progress**