Modeling Natural Catastrophes: A Primer

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Carvill/ReAdvisory

Carvill

REINSURANCE INTERMEDIARY

Independence ■ Integrity ■ Service ■ Innovation

Agenda

- Who are Carvill and ReAdvisory?
- Hurricane Modeling
- Modeling Events
  - Seasonal forecasting
  - Real-time forecasting
- Insured Loss Modeling

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Carvill & ReAdvisory

Carvill

- One of the largest privately held international reinsurance intermediaries
- 30 years of success in a constantly evolving market
- Concentrated focus on treaty reinsurance, captives / mutuals, and specialist risk groups
- Long standing commitment to excellence in technical expertise and service standards
- A track-record of market leading product development
  - The first casualty cat bond
  - Reinsurance recoverable credit protection
  - Exchange-traded hurricane futures and options

ReAdvisory

- A service of Carvill
- Actuarial and cat modeling consultancy practice.

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Hurricane Modeling

Hurricane modeling breaks down in two major ways

- Forecasting actual events
- Modeling insured losses

The sciences do not try to explain, they hardly even try to interpret, they mainly make models.
John von Neumann

Terminology

- Skill
  - A statistical evaluation of the accuracy of forecasts. The evaluation is typically made with respect to a reference model
- Statistical Model
  - A model which is derived from a statistical analysis of the physical variables.
  - This class of model typically describes seasonal forecasts and most cat models
- Dynamical Model
  - A model which is based on the actual physics of the process.
  - This class of model encompasses global weather models and most models of live hurricane
- Ensemble Model
  - Multiple runs of the same model started with slightly differing initial conditions
  - Used to evaluate the range of potential outcomes given imperfect knowledge of the initial state

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Modeling Events

Forecasting of actual events comes in two flavors:

- Seasonal forecasting
  - An attempt to predict the level of hurricane activity for an upcoming hurricane season
- Real-time forecasting
  - An attempt to predict where an actual hurricane will go, and with what strength

There are many methods for predicting the future. For example, you can read horoscopes, tea leaves, tarot cards, or crystal balls. Collectively, these methods are known as "nutty methods." Or you can put well-researched facts into sophisticated computer models, more commonly referred to as "a complete waste of time."

Scott Adams

Seasonal Forecasts

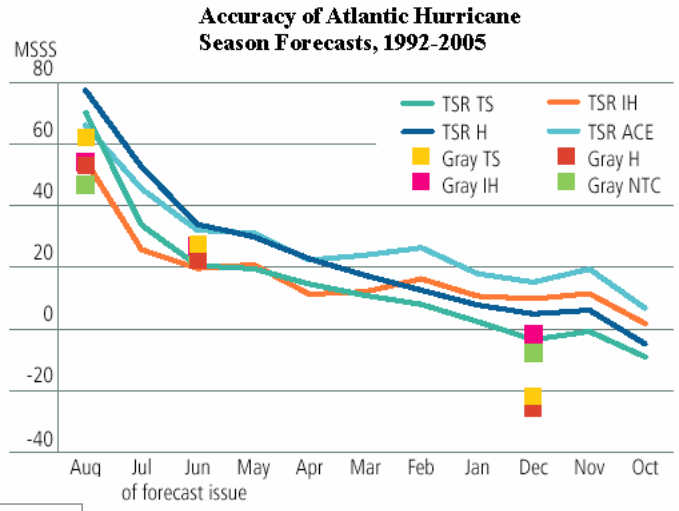
- Seasonal forecasts:
  - Statistical/Teleconnection
    - N(hurricanes) = fn(V1, V2, V3,…)
  - Depend on a variety of inputs
    - Colorado State forecasts use between 3 and 6 predictors
    - TSR forecasts use 2 predictors

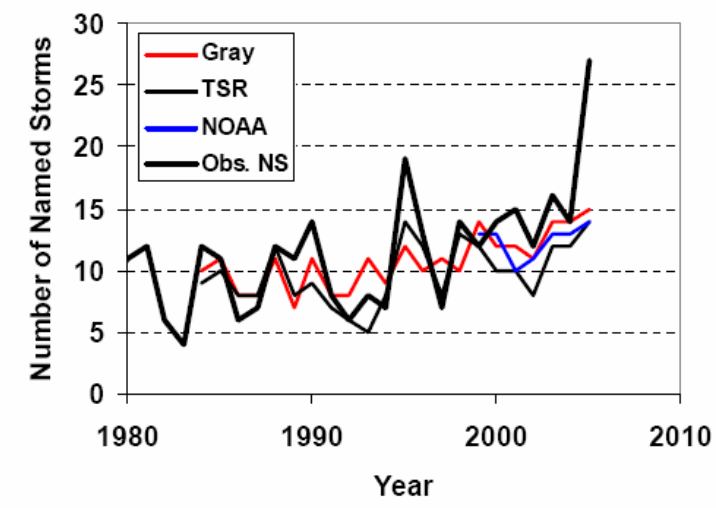
- Seasonal forecasts are essentially predicting the general climate state expected during hurricane season
  - Atlantic Sea Surface Temperature
  - El Niño/La Niña
  - Quasi-Biennial Oscillation

Seasonal Forecasts

- Seasonal Forecast Skill
  - Figure from Jeff Masters at Weather Underground

    A comparison of the forecasts with a 'forecast' of just assuming climatology





- Figure from Greg Holland, NCAR

  Paper submitted to GRL "On the Skill of Seasonal Tropical Cyclone Forecasts for the North Atlantic"

Seasonal Forecasts

- Seasonal forecasts only begin to show skill as we approach hurricane season
- Reinsurance renewal periods (late year & mid Spring) occur before seasonal forecasts have any reliability
- Seasonal forecasts do not have, and should not have, bearing on reinsurance renewal pricing
- Seasonal forecasts have some ability to capture the mean activity rate, year on year.
- Seasonal forecasts are pretty hopeless at capturing the actual activity in any one year

Moral: Disregard the forecast numbers and concentrate on the underlying climate

Real-time Forecasts

Live storms tracks are influenced by

- Steering flow
  - Troughs and ridges
  - High and low pressure systems
- Recurving tendency

Live storm intensity is influenced by

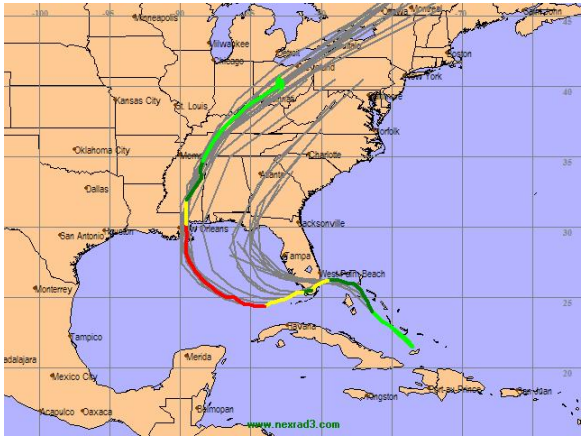
- Water temperature
- Wind shear
- Water vapor
- Outflow

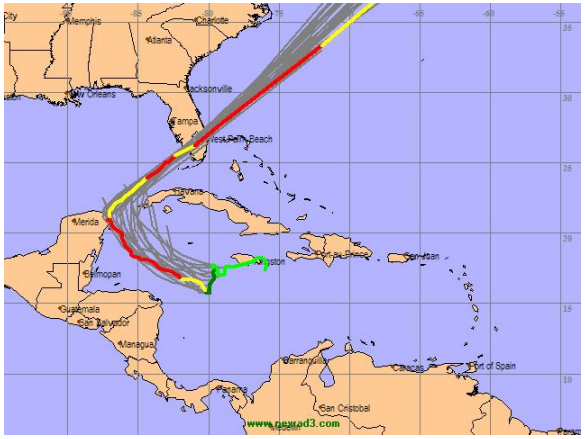
Forecasting has improved over the last 15 years

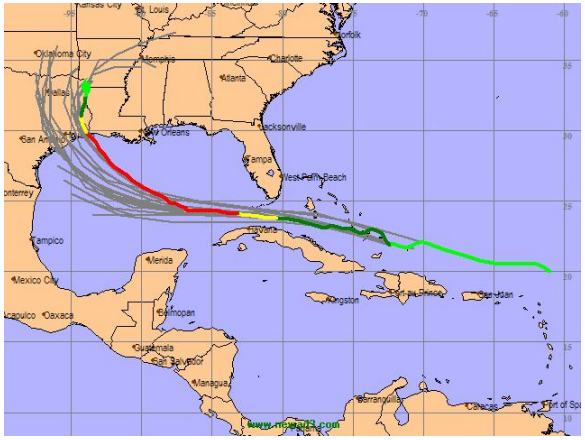
- Significantly for track
- Marginally for intensity

Real-time Forecasts

Some situations are easier to forecasts than others.



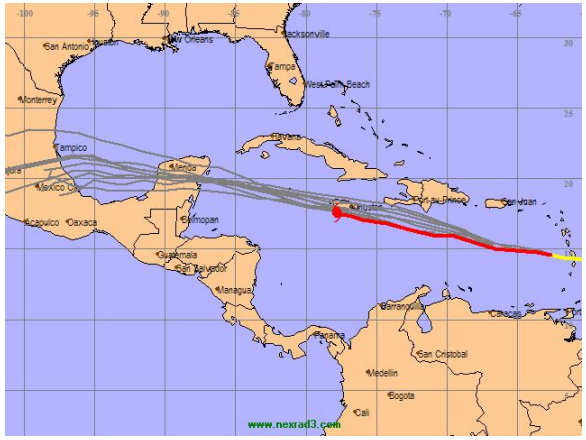


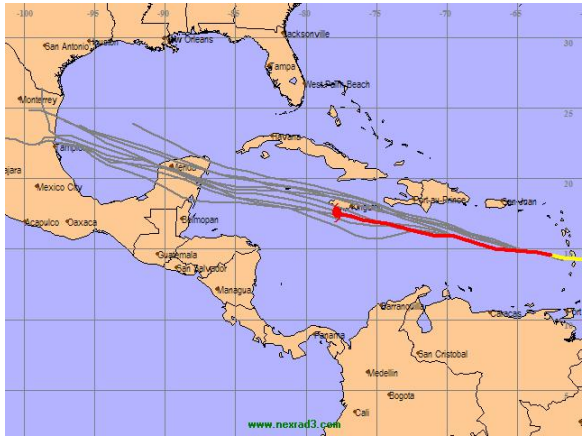


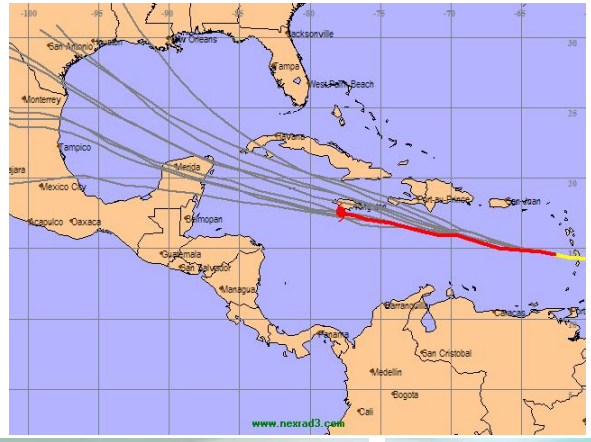
- Top left: Katrina
- Top right: Wilma
- Bottom: Rita

Real-time Forecasts

The NHC forecast is a consensus/ensemble forecast based on a suite of constituent models. Some perform better than others in given situations.







- Dean model forecasts
  - Top left: NOGAPS
  - Top right: HWRF
  - Bottom: GFDL

Summary

Seasonal Forecasts

- Seasonal forecasts have little use in reinsurance renewals
- Forecast numbers can be misleading
- The general trend for the hurricane season (e.g. ‘above average’) has some merit

Real-time Forecasts

- Forecasts track skill has improved significantly
- The ensemble forecast method produces the most skillful forecast
- It’s hard to beat the NHC official forecast

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Insured Loss Modeling

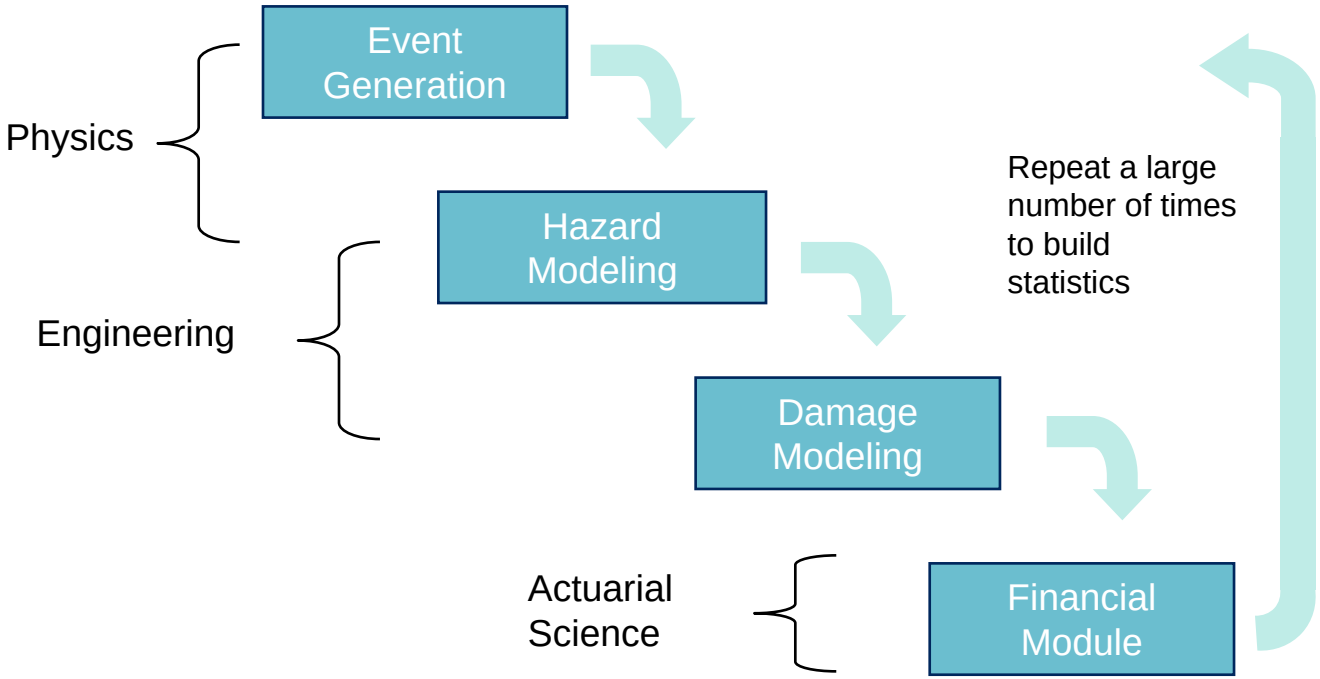
- Catastrophe modeling is a very complicated proposition
- Having an in-house model provides a sanity check but if every re/insurer had an in-house model how would anyone trade?
- Commercial cat models are a necessary evil.
- All of the commercial models are in general statistical.

There are 3 model vendors who have developed catastrophe models for the re/insurance community -

- Applied Insurance Research
- EQE
- Risk Management Solutions

Models are to be used, not believed
Henri Theil

Basics of a Cat Model



Event Modeling

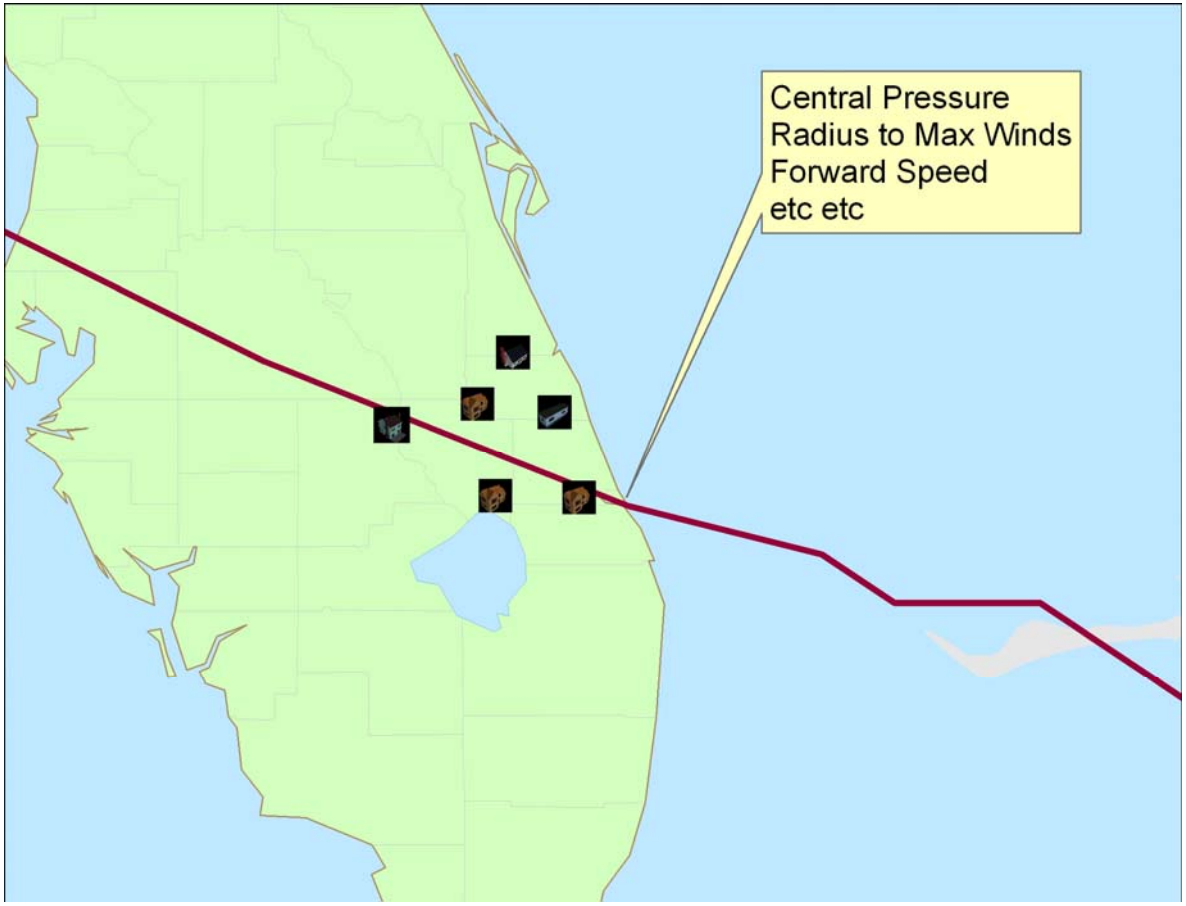
All current cat models generate events in a similar way:

- Gather historical event data
- Parameterize historical events
- Generate probability density functions (PDFs – the set of individual outcome probabilities) of historical event parameters
- Sample PDFs to generate a synthetic event

This process is used for tropical cyclones, windstorms, tornado outbreaks, flood events and earthquakes.

This paradigm is changing as more numerical modeling techniques are used.

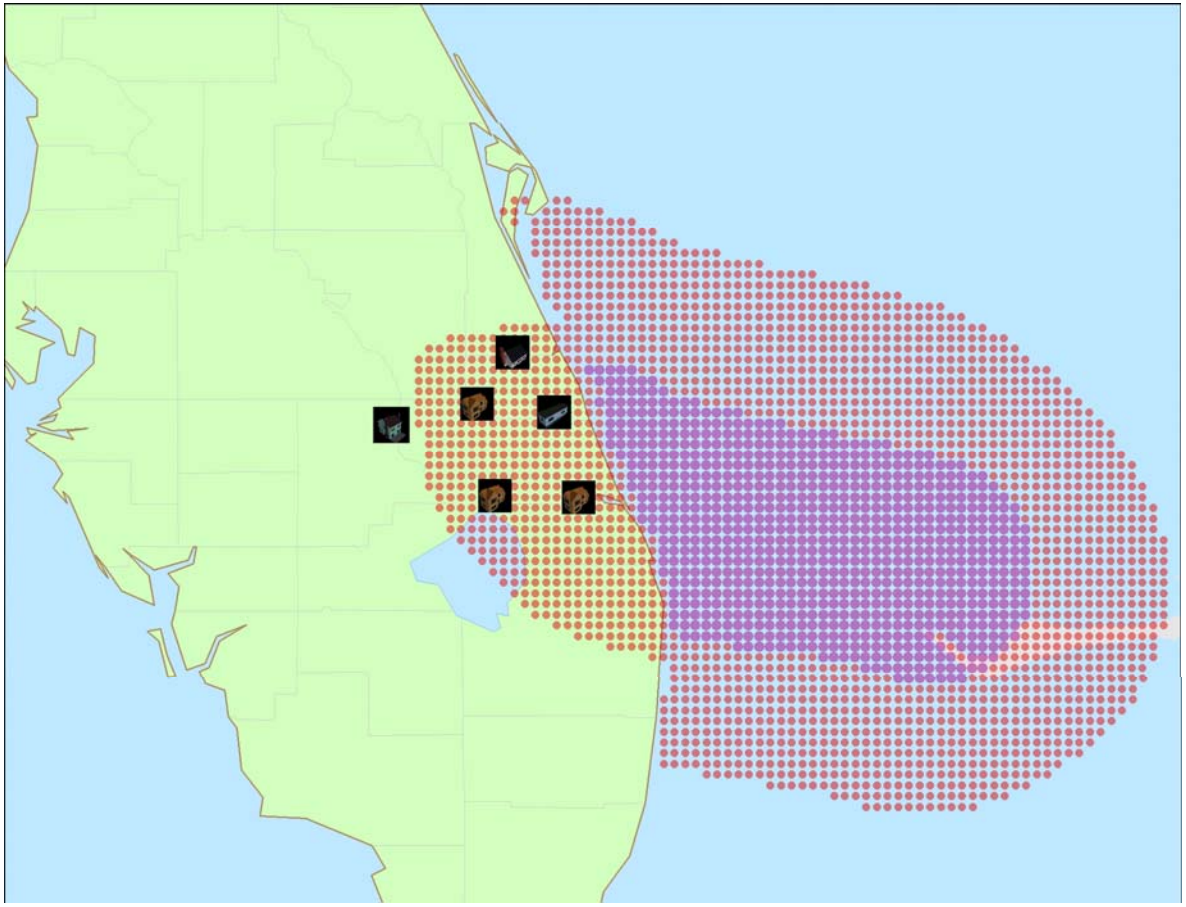
Event Modeling – example



Hazard Modeling

- The hazard is the consequence of the event which causes damage – for a hurricane it is the wind at ground level, for an earthquake the ground shaking, etc.
- Hazard modeling is more mechanistic than event generation – it could be considered to be more ‘engineering’ than ‘physics’. There is typically no stochastic process involved in the hazard component

Hazard Modeling – example



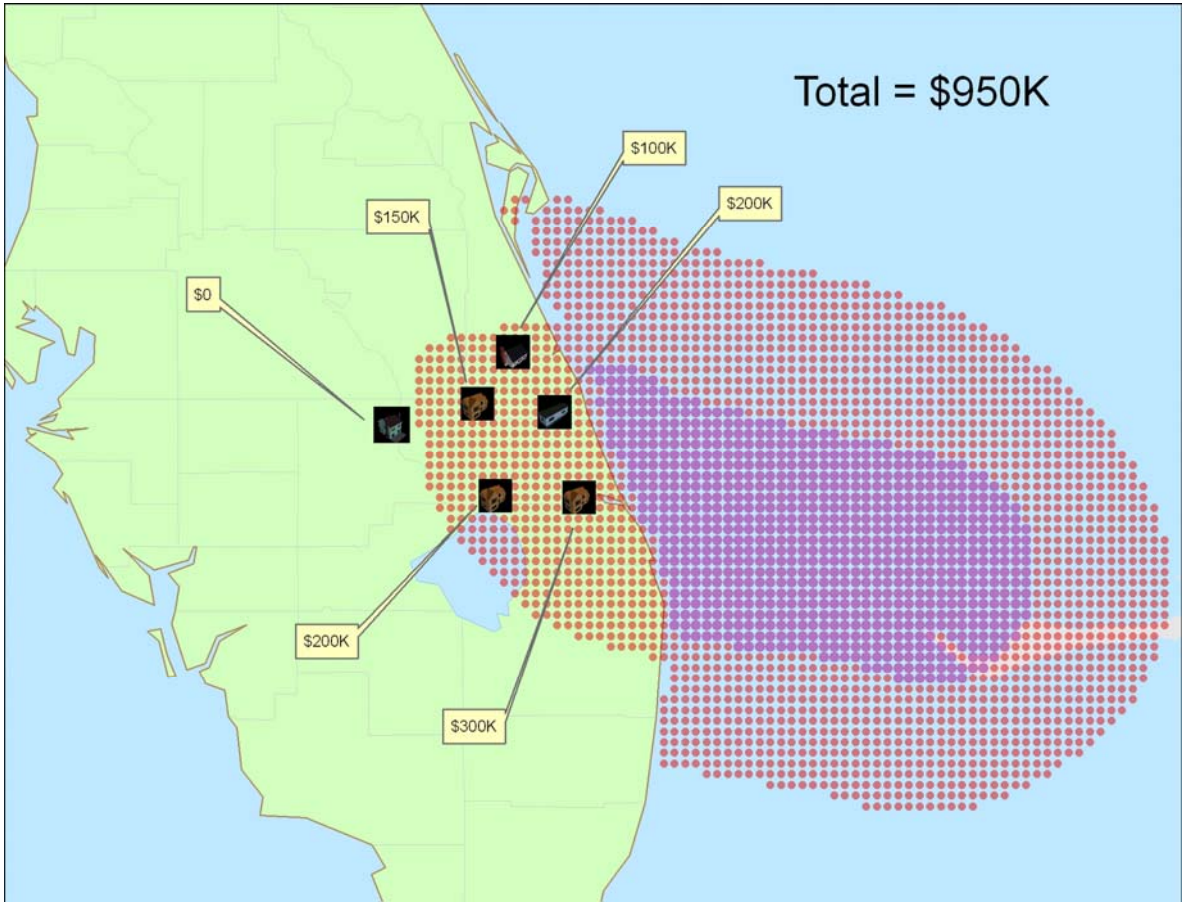
Damage Modeling

- Given a hazard (windspeed, ground shaking), the damage produced by this hazard on a building must be determined. This is strictly an engineering problem.
- Using insurance claims data and engineering studies, damage curves are generated which relate the amount of damage suffered by a building of a certain type to the magnitude of the hazard affecting that building.
- Building type is classified in a number of ways:
  - Construction
  - Occupancy
  - Age
  - Height
- Further, the damage curves are modified by various building attributes such as cladding, building code and enforcement etc.

Financial Modeling

- Finally, once the event has been turned, via the hazard model, into damage, the damage can be turned into a financial cost.
- The actual specifics of this depend on the re/insurance contract under examination. The financial module must be able to value all types of insurance products.
- The output of the entire process is a loss and various statistics about the loss.
- It should be noted that the loss represents the mean value the re/insurance contract would be expected to pay when calculated over a very large number of years. However, insurance contracts typically last 1 year (i.e. the current or the following year). Is this inconsistent?

Damage & Financial Modeling – example

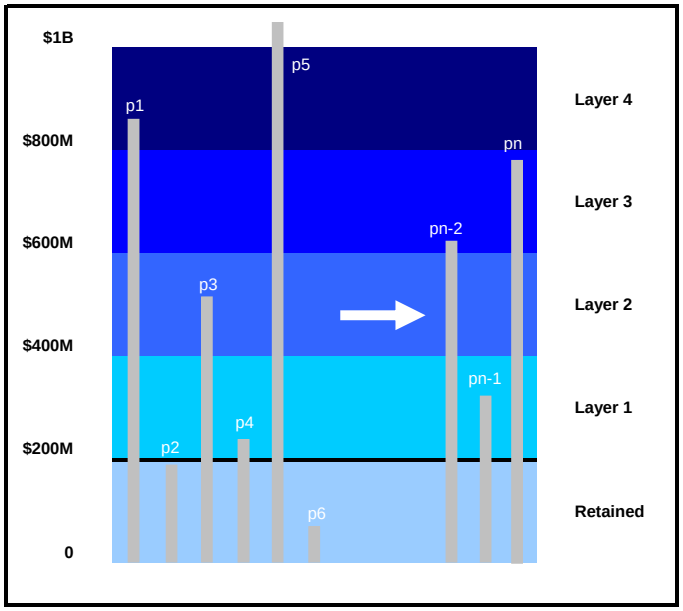


Pricing Reinsurance

- Many simulated events are applied to the reinsurance structure
- The loss cost for each layer is determined:

$$LC(layer) = \sum_{events(i)} p_i Loss(layer)_i$$

- Pricing for each layer equals loss cost plus loadings



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Conclusions

- Hurricane modeling has improved significantly over the last 15 years
- Some models are more useful than others…

It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so.
Mark Twain