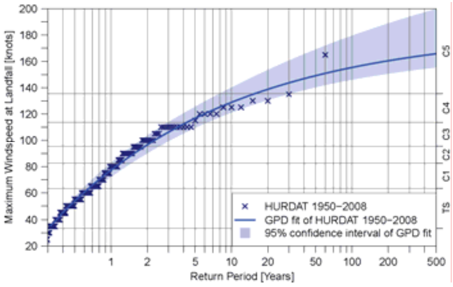
The Actuarial Profession
making financial sense of the future

GIRO Conference 2011, Liverpool
Jan Kleinn (Aspen Re) and Timothy Hall (NASA-GISS)

Tropical cyclone return periods

Comparison of two methods

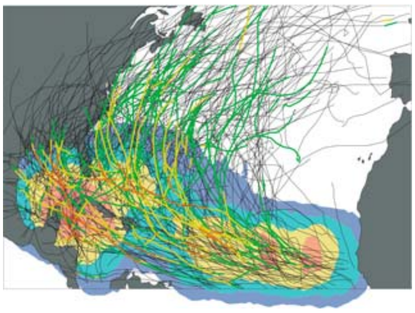
Extreme Value Theory: Generalized Pareto Distribution (GPD) to historic landfall data



Easy construction, model derived directly from quantity of interest, no bias.

Low precision, high uncertainty on mean.
High sensitivity to individual storms error.
Not possible in low activity regions.

Stochastic model of TC lifetime based on full storm data. Generate synthetic storms to calculate return periods at landfall.



Much more data used. Increased storm count means precise estimates at high geographic resolution, in regions of low activity, in specific climate states. Easy to analyse correlations.

Added complexity,
possibility of model bias.

Motivation

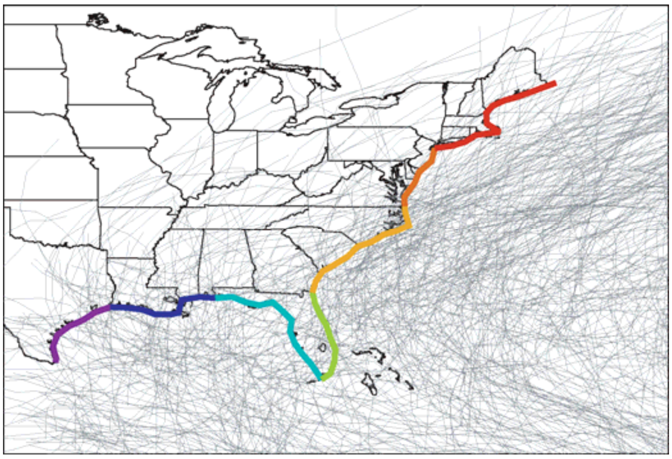
- Reinsurers need to know losses with return periods of 100, 250, and 500 years
- Historic data is not enough
- Typical cat model consists of:
  - stochastic event set
  - wind field
  - vulnerability functions
  - financial model

Motivation

- How can stochastic event sets be validated?
- What is the uncertainty of these models?
- Comparison of stochastic event set and extreme value statistics (Generalized Pareto Distribution, GPD)

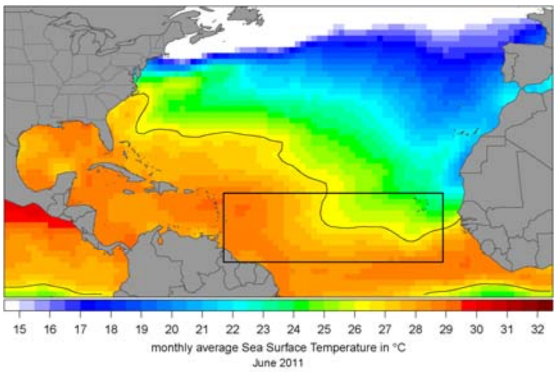
Region of interest

Atlantic basin, US coast line landfall regions

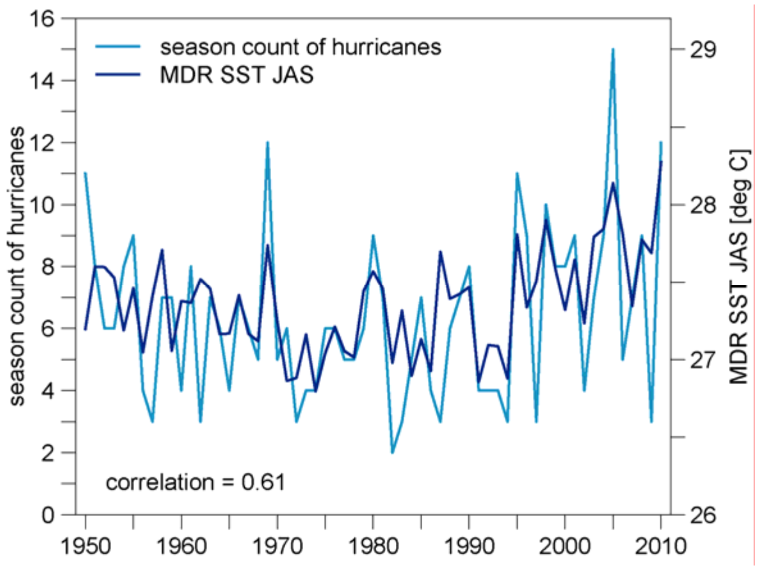


Stochastic model

- Cyclone genesis, dependent on
  - El Niño Southern Oscillation (ENSO)
  - Main development region sea surface temperature (MDR SST)
- Storm tracks
- Storm intensity

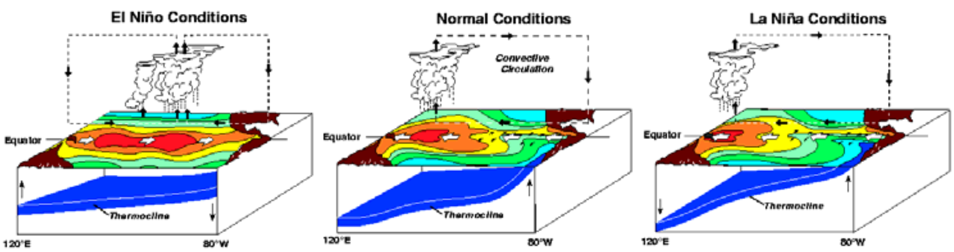


MDR SST and hurricanes

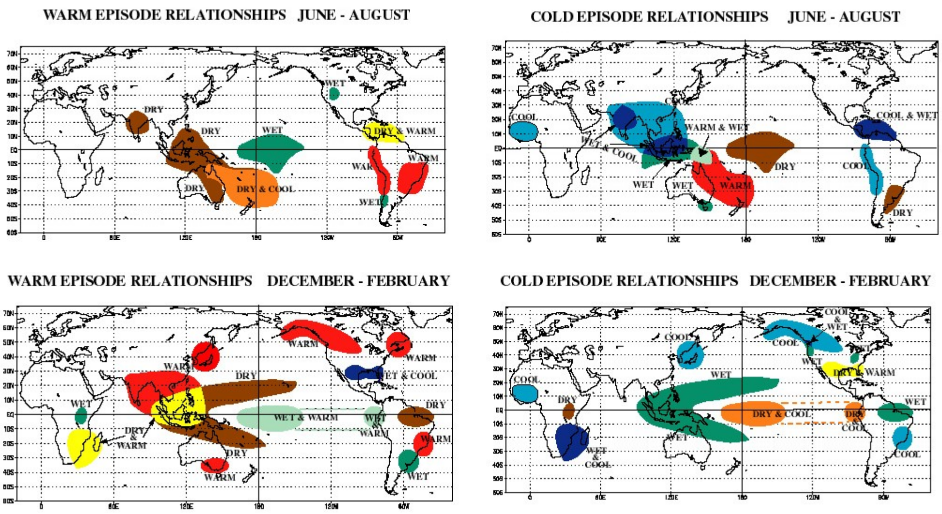


ENSO and El Niño

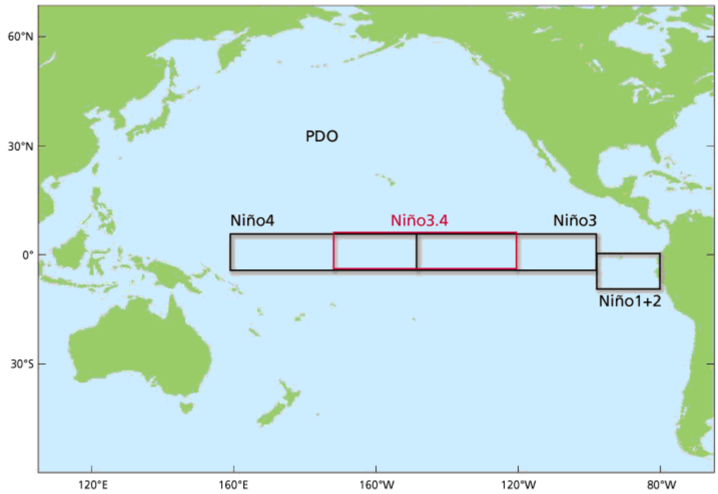
- ENSO: El Niño Southern Oscillation
- Oscillation in Pacific SST and trade winds



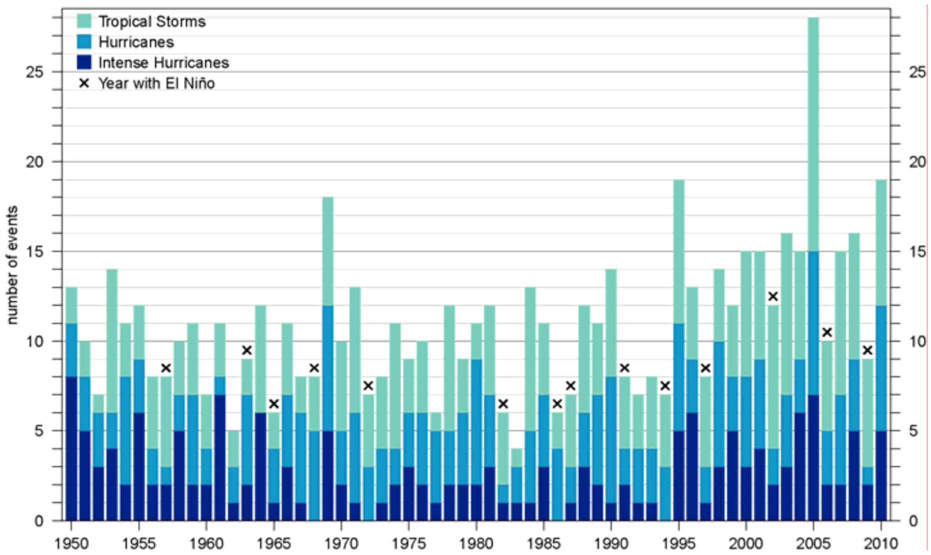
Global influences of ENSO



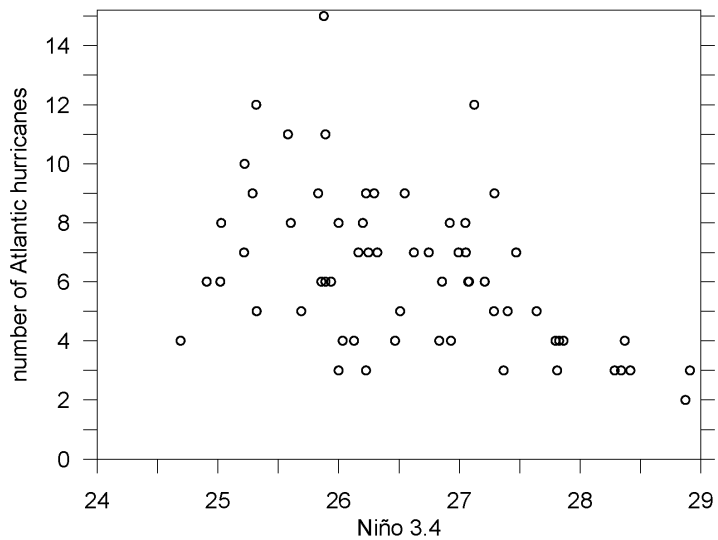
El Niño indices



El Niño and hurricanes

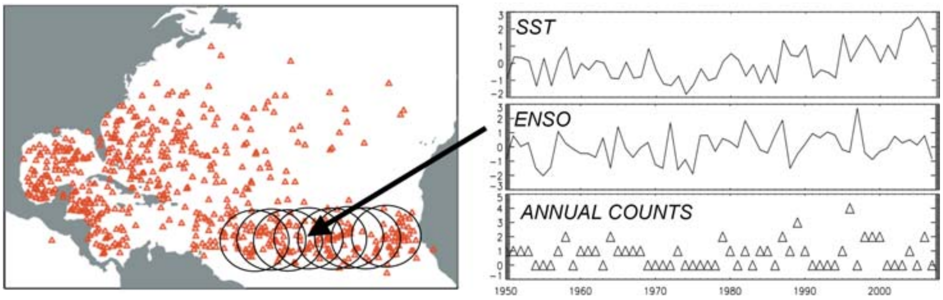


Correlation Niño 3.4 and Atlantic hurricanes



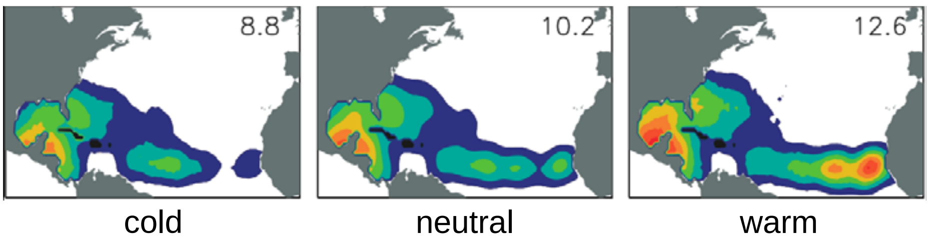
Cyclone genesis

- Local optimized Poisson regression dependent on seasonal MDR SST and ENSO



Cyclone genesis

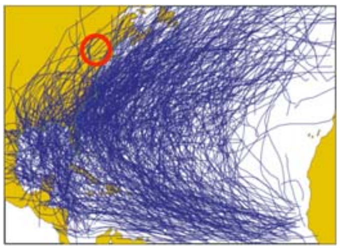
- Increasing number of cyclones in warm conditions
- Changes in genesis pattern

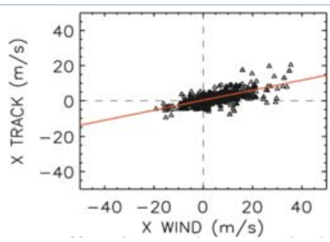


Storm track model

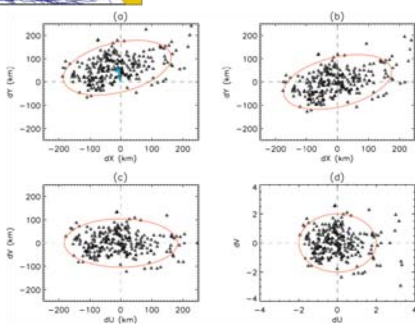
- Regression of nearby historic tracks on upper level seasonal composite winds
- Modeling of errors provides stochastic component and is accomplished by standardization and lag-one autoregression with a noise term

Storm track model





Means by regression on upper-level winds



Model residuals

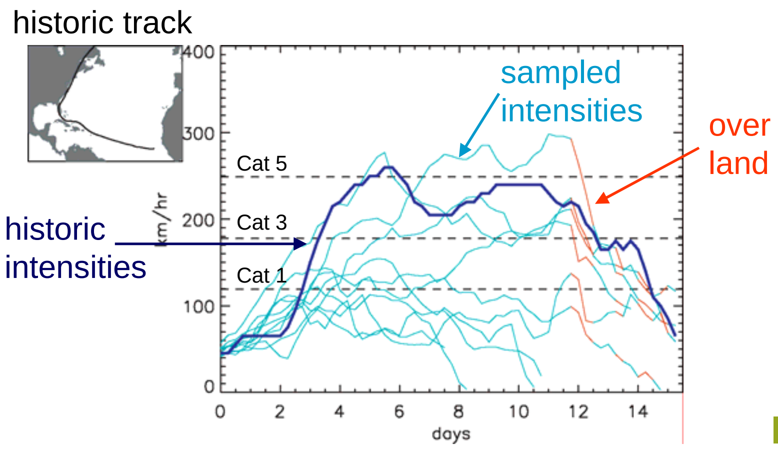
Storm intensity model

- Local regression of 6-hourly intensity changes with MDR-SST and ENSO
- Seperate regressions for land, ocean, and early development

- Only 25% of variance can be explained, residuals are sampled for random term.

Storm intensity example

Hurricane Donna, 1960

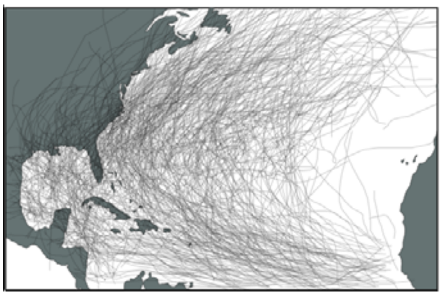


Track model simulations

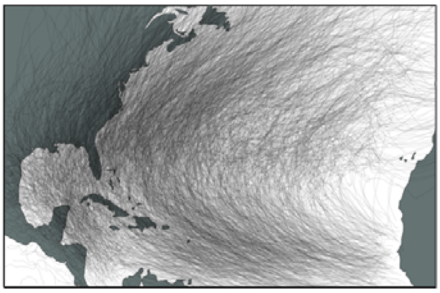
Generate large synthetic storm sets to compute landfall rates:

- Model Evaluation:
  Generate ensemble of synthetic 1950-2008 periods to evaluate model against historical TCs. Compute return-period curves for each ensemble member. Historical curve should look like sample from model ensemble.
- Model Uncertainty:
  Generate 1000-year simulation to estimate mean return-period curve. Re-construct model multiple times with random 20% data drops, each time computing return periods. Spread is measure of uncertainty in mean return periods.

Track model simulations



historical
1950-2008

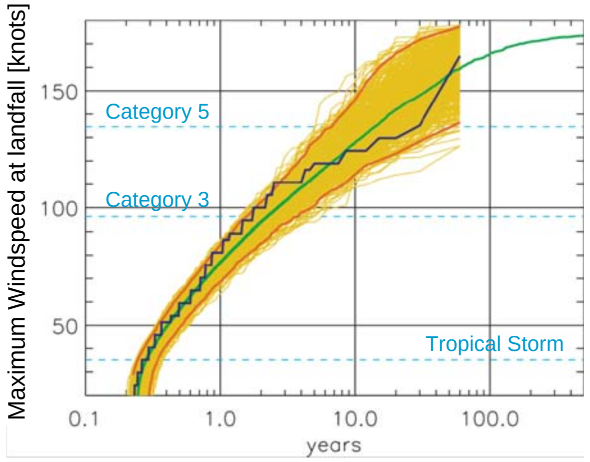


synthetic
1000 years

For further detail on genesis and track model:
– Hall & Jewson, Tellus, 2007
– Hall & Jewson, J. Appl. Meteorol. and Clim., 2008
– Yonekury & Hall, J. Appl. Meteorol. and Clim., 2011

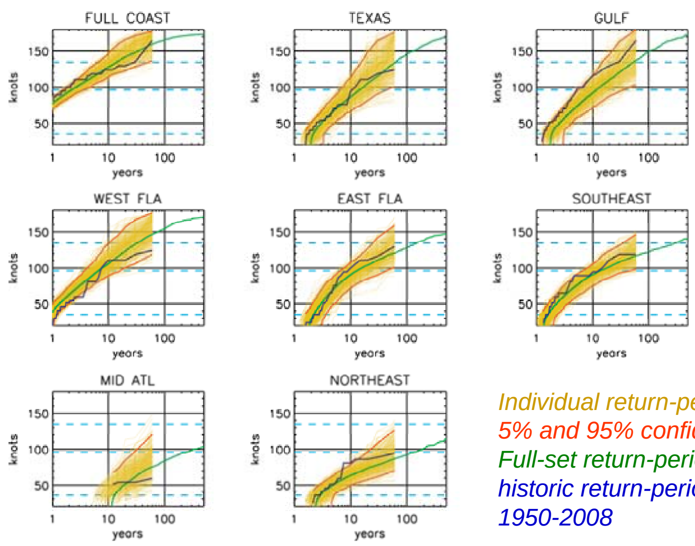
Stochastic model results

– US coast landfalls
– samples of 59 years each, same as historic data



Individual return-period curves
5% and 95% confidence bounds
Full-set return-period curve
historic return-period curve, 1950-2008

Regional Differences



Individual return-period curves
5% and 95% confidence bounds
Full-set return-period curve
historic return-period curve, 1950-2008

Extreme value analysis

- Fit distributions or rare and extreme events
- Allows estimation of return periods and confidence intervals
- Two classes:
  Block Maximum & Peak over Threshold
- 3 parameters:
  shape, scale, location/threshold

Block maximum approach

- Generalized Extreme Value distribution (GEV)
- Ideal when you have one strong event per time period, e.g. yearly maximum runoff
- General form of
  - **Gumbel**: shape = 0
  - **Fréchet**: shape > 0
  - **Weibull**: shape < 0

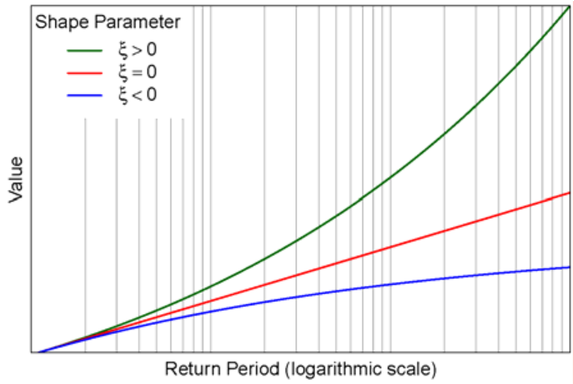
Peak over threshold (POT)

- Generalized Pareto Distribution (GPD)
- Ideal if you have several or no events per time period, e.g. hurricanes

shape = 0
exponential distribution

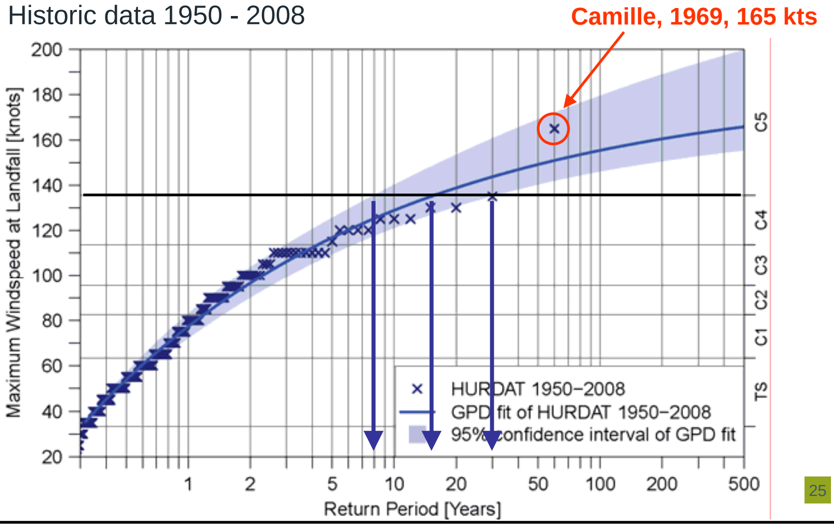
shape < 0
upper limit

shape > 0
no upper limit

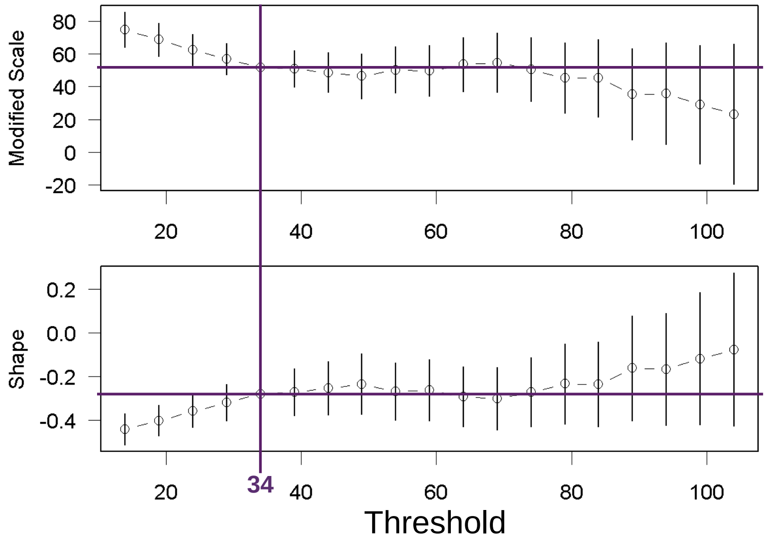


Generalized Pareto fit of US hurricane landfalls

Historic data 1950 - 2008

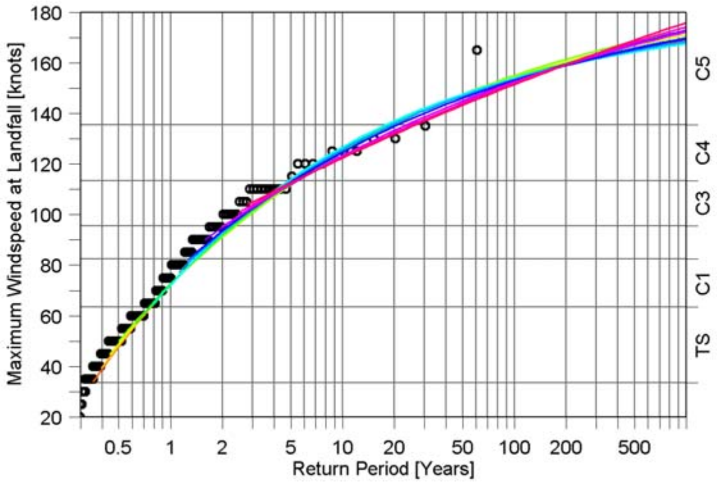


Choice of threshold



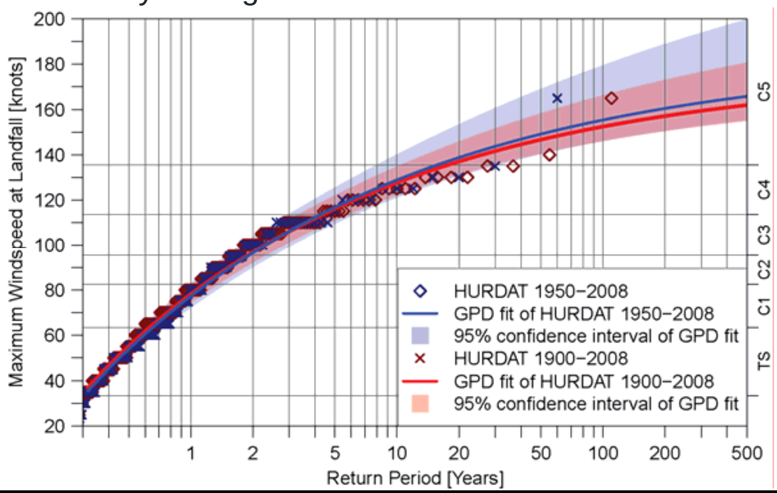
Choice of threshold

thresholds 34 – 104 knots



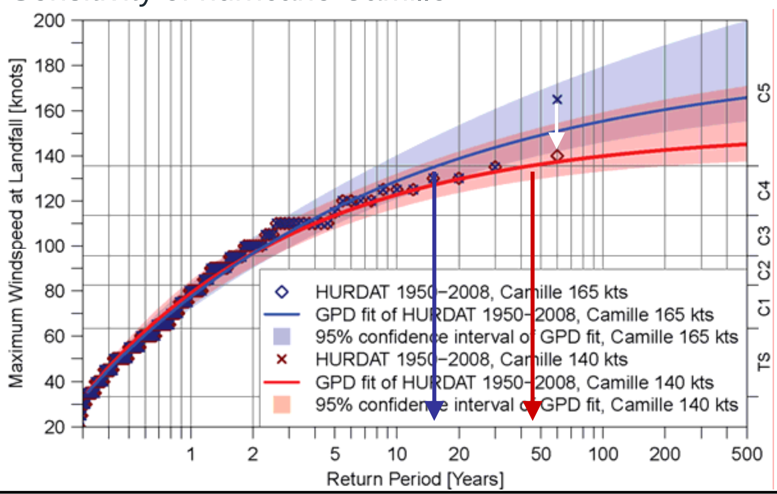
Generalized Pareto Distribution

Sensitivity to length of dataset



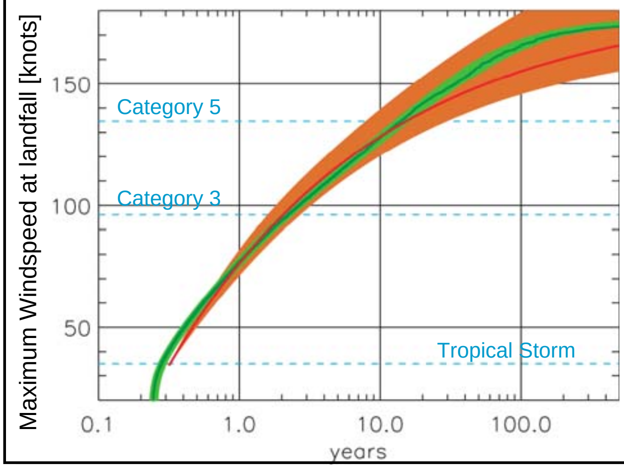
Generalized Pareto Distribution

Sensitivity of hurricane Camille



Model Uncertainty vs. GPD

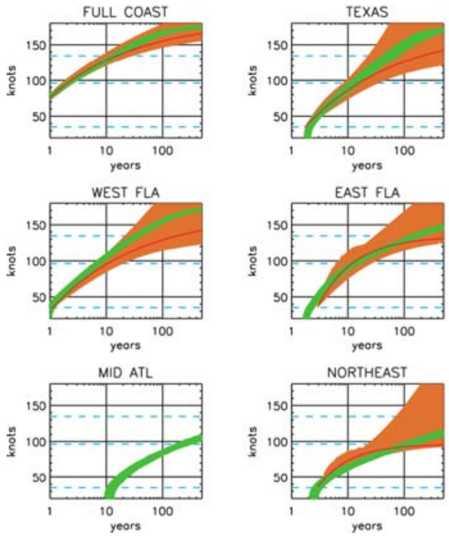
– US coast landfalls
– reconstruct model multiple times with data drops



GPD fit of historic data (1950-2008) with 95% confidence bounds

Track model constructed multiple times with random 20% data-year drops, 90% confidence bounds.

Regional Differences



GPD fit of historic data (1950-2008) with 95% confidence bounds
Track model constructed multiple times with random 20% data-year drops, 90% confidence bounds.

Conclusions

- Good agreement of stochastic model with historic data along entire US coast.
- Biases exist on regional level.
- Uncertainty of GPD higher than of stochastic model.
- Stochastic model is robust.
- Stochastic model allows sensitivity analyses with MDR SST and ENSO.

Conclusions

- Stochastic models are a useful tool to extend historic landfall data.
- Ground truth remains unknown.
- Stochastic models and GPD are backward looking only.
  - Future hurricanes might be different.
  - Future hurricanes might change our results.

Questions or comments?

Expressions of individual views by members of The Actuarial Profession and its staff are encouraged.

The views expressed in this presentation are those of the presenter.