# Estimating Return Levels of Hurricane Katrina

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# Outline

- Background
- Model results
- Method
- Calibrating prehistorical overwash events
- Forecasting insured losses

## Background

- The rarity of severe hurricanes implies that empirical estimates of return periods likely will be unreliable.

- Extreme value theory provides models for rare wind events as well as a justification for extrapolating to levels that are much greater than have already been observed.

- Definitive answers to questions about whether hurricanes will be more intense or more frequent in a future of global warming require long records.
  - The longest records available are near the coast.

# Background

- Probability models of extreme winds in tropical cyclones in the literature.

  - Darling (1991): *empirical model* to estimate local probabilities of hurricane wind speeds exceeding specified thresholds.

  - Rupp and Lander (1996): *method of moments* on annual peak winds over Guam to determine the parameters of an extreme value model leading to estimates of recurrence intervals for extreme typhoon winds.

  - Heckert et al. (1998): *peaks-over-threshold* method and a reverse *Weibull distribution* to obtain mean recurrence intervals for extreme wind speeds at consecutive mileposts along the U.S. coastline.

  - Chu and Wang (1998): various *parametric distributions* to model return periods for tropical cyclone wind speeds in the vicinity of Hawaii.

  - Jagger et al. (2001): *maximum likelihood (ML) estimation* to determine a linear regression for the scale and shape parameters of the *Weibull distribution* for hurricane wind speeds in coastal counties.

  - Pang et al. (2001): *Bayesian approach* to estimating parameters from a *Weibull distribution* using wind speed data.

## Background

- We build on these earlier works but our efforts differ in some crucial ways.

1. We interpolate 6-hourly hurricane positions and intensities to 1 hr.  This allows us to determine the most extreme wind for hurricanes entering each region without adding a bias due to fixed regional boundaries.

2. We use extreme value distributions.

## Background

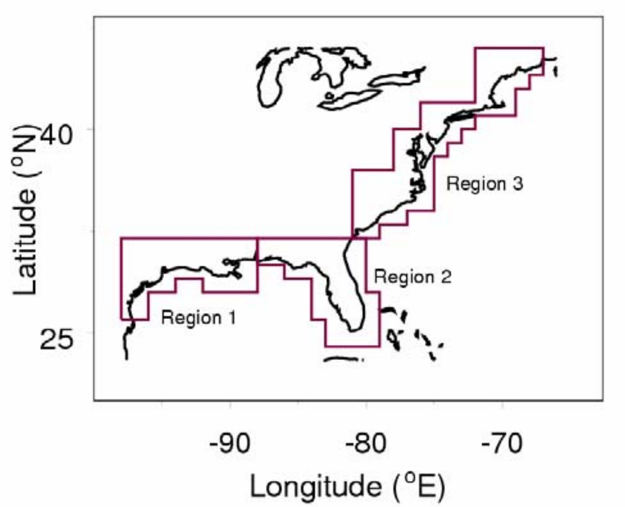
- We answer the following questions.
  1. What are the return levels of maximum hurricane winds in near-coastal regions over 5, 10, 50, and 100 years?
  2. Are the return levels different from region to region?
  3. What is the maximum possible hurricane wind speed level?

- We answer these questions by statistically modeling the maximum wind speeds near the coast.
  - We use a ML approach and use data only over the reliable period over records from 1899-2004.

# Model results

Hurricane return levels by region

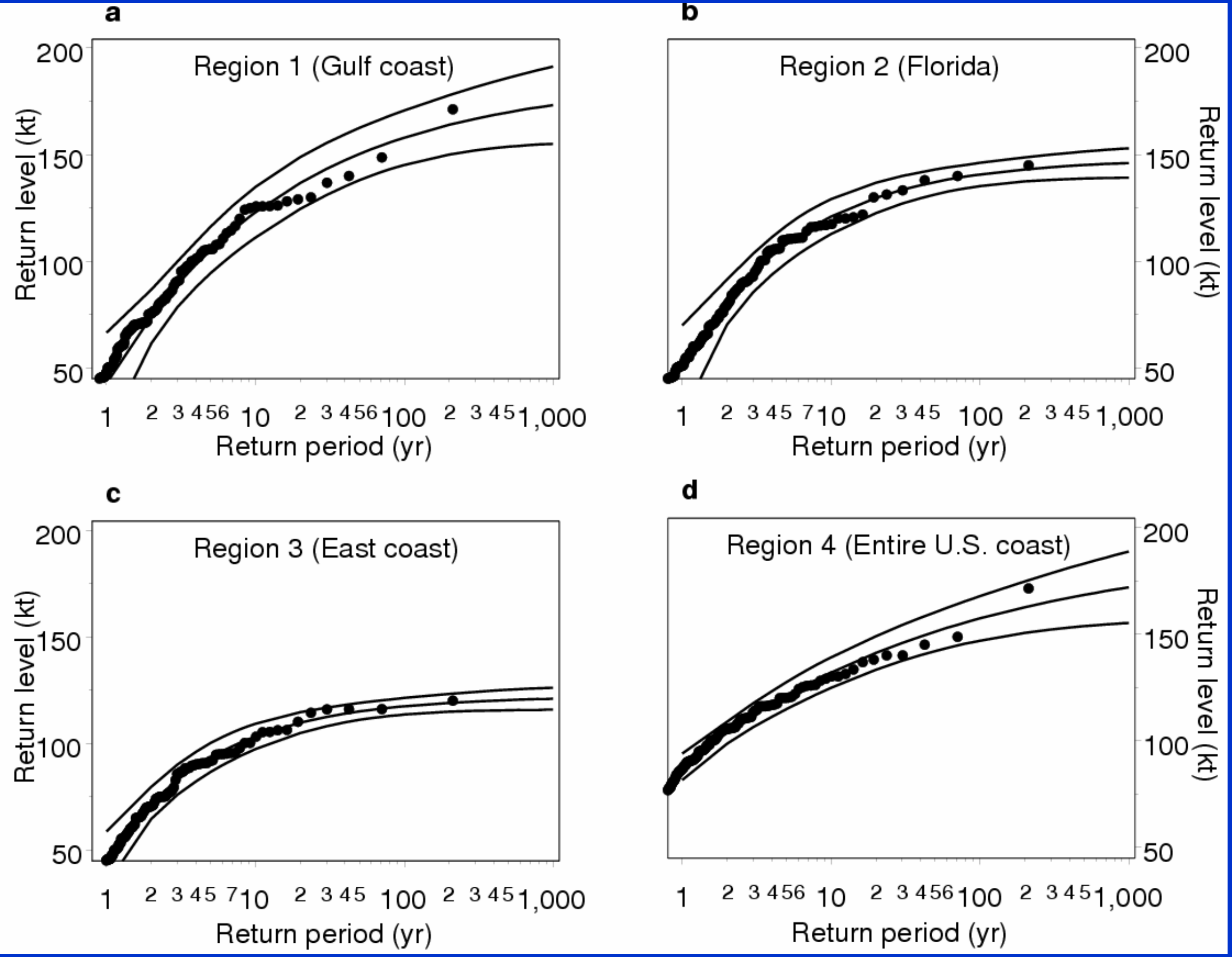
| Return Period (yr) | Region 1 Gulf coast | Region 2 Florida | Region 3 East coast | Region 4 Entire coast |
|---|---|---|---|---|
| 5 | $105 \pm 11$ | $108 \pm 9$ | $93 \pm 7$ | $121 \pm 6$ |
| 10 | $123 \pm 12$ | $121 \pm 8$ | $103 \pm 6$ | $132 \pm 7$ |
| 50 | $150 \pm 12$ | $137 \pm 6$ | $115 \pm 4$ | $151 \pm 9$ |
| 100 | $158 \pm 13$ | $141 \pm 5$ | $117 \pm 4$ | $157 \pm 10$ |
| 500 | $170 \pm 16$ | $145 \pm 6$ | $120 \pm 5$ | $168 \pm 15$ |




**Region 4 = Regions 1 + 2 + 3.**

- Values (kt) are based on an extreme value model for the maximum wind distribution for each hurricane and a Poisson model for the yearly hurricane rate.
- Model parameters are estimated using the ML method.
- Values to the right of the +/- refer to half the 95% confidence interval.

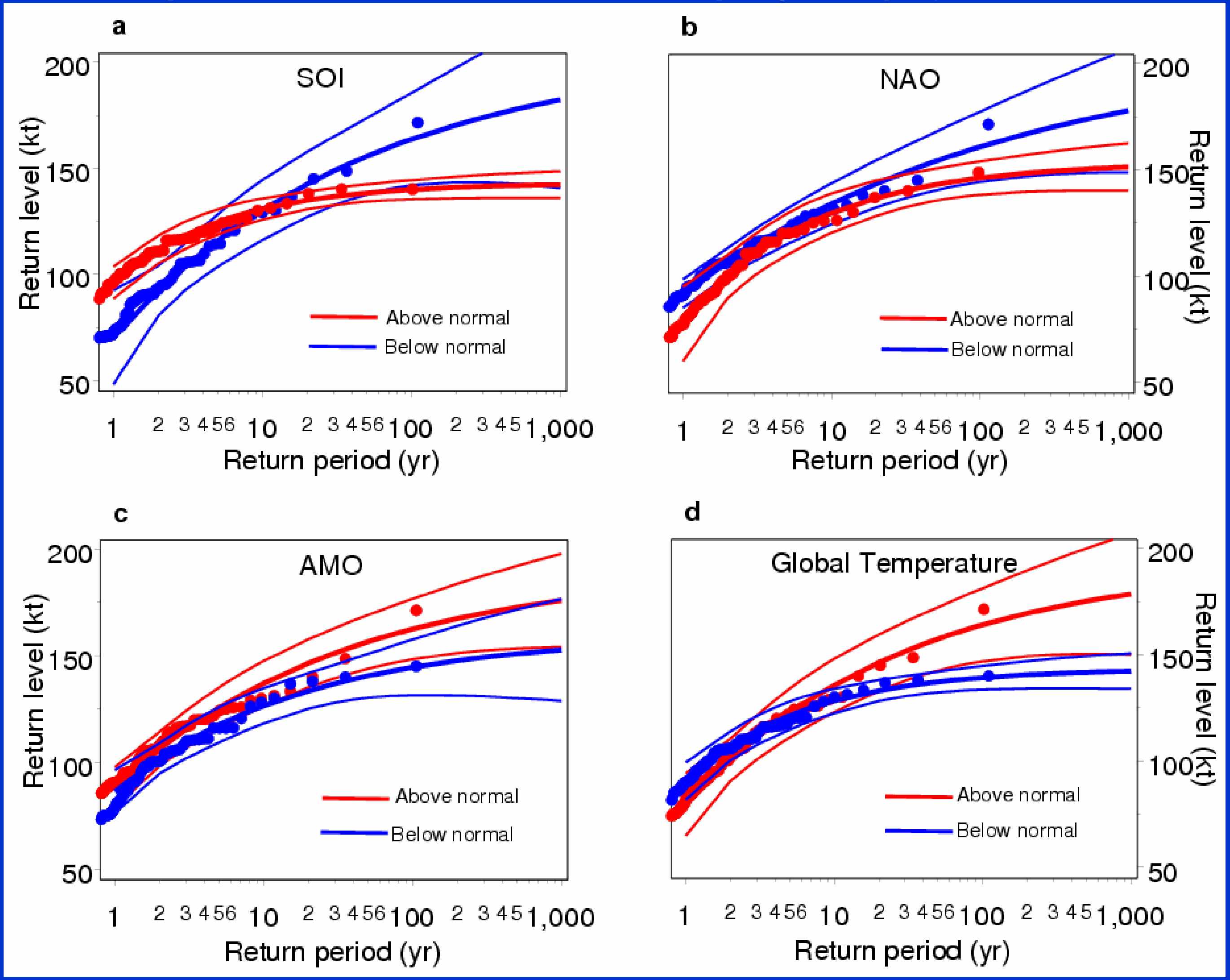
# Model results




Curves are based on an extreme value model and asymptote to finite levels as a consequence of the shape parameter having a negative value. Parameter estimates are made using the ML approach. The thin lines are the 95% confidence limits. The return level is the expected maximum hurricane intensity over *p*-years. Points are empirical estimates and fall close to the curves.

# Models results

**Return level plots for the entire U.S. coast (Region 4) by climate factors.**




Curves are based on an extreme value model using a ML estimation procedure. Red (blue) lines and points indicate above (below) normal climate conditions.

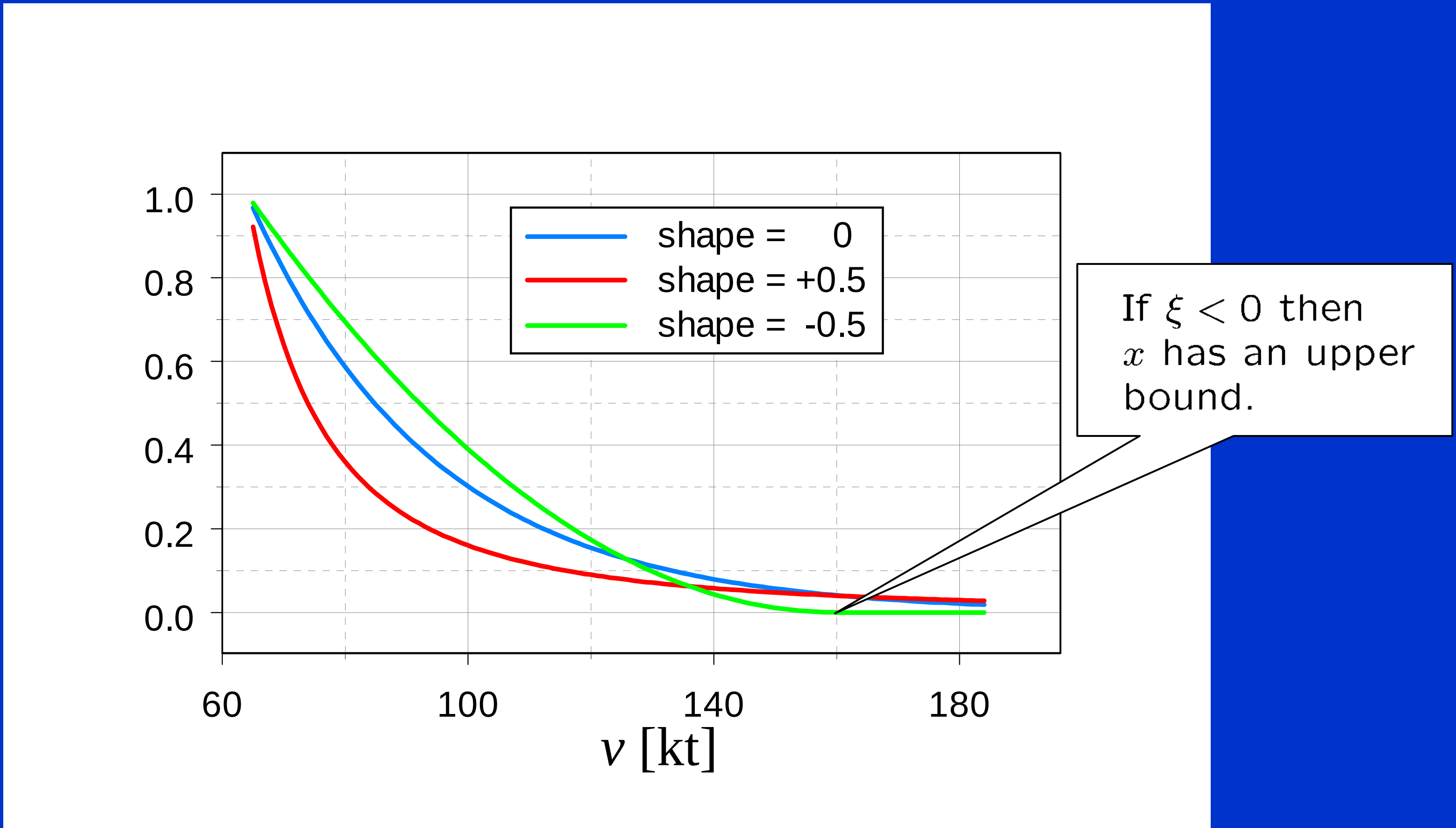
# Method

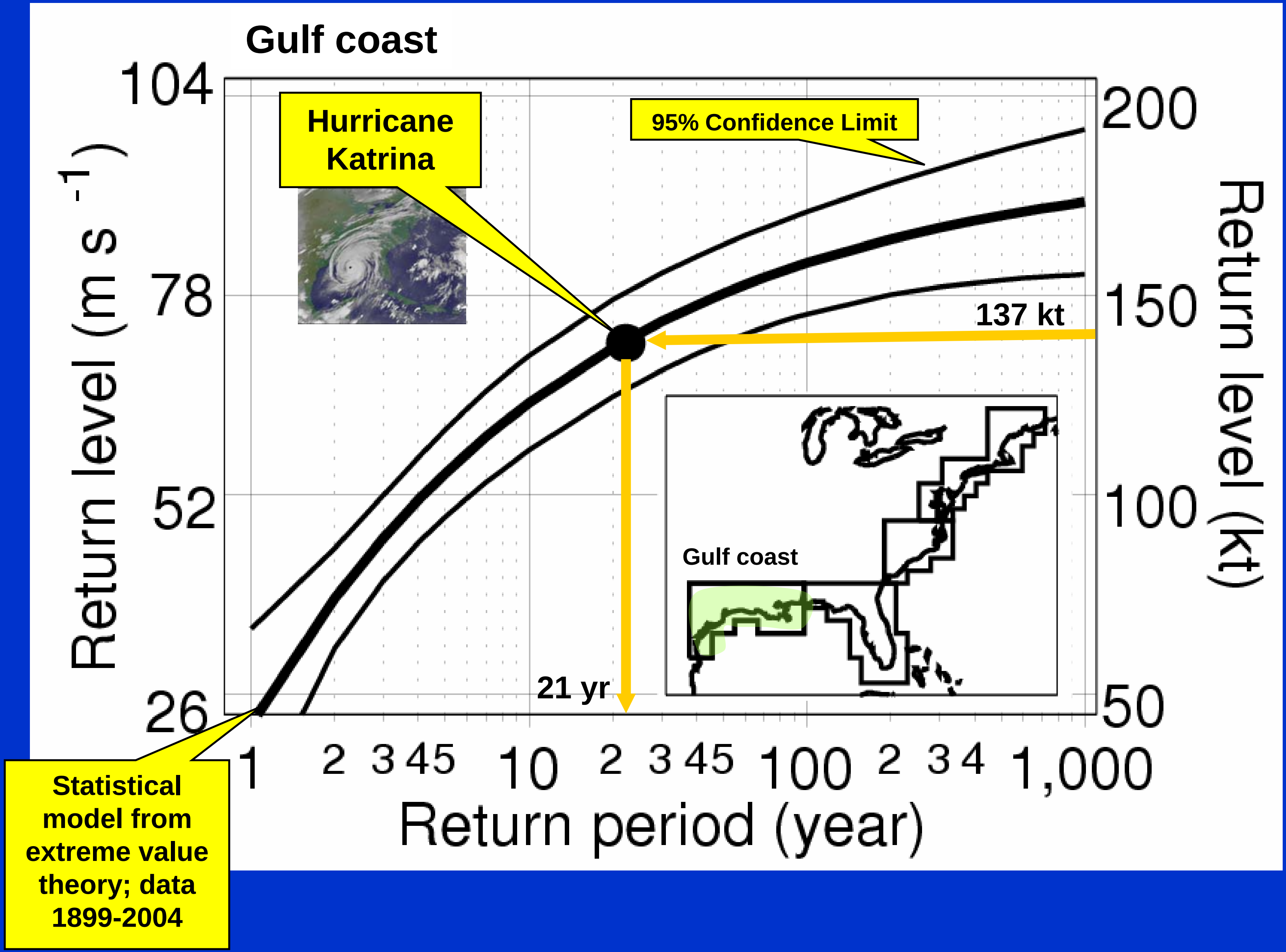
Example: let $x$ be a hurricane wind speed observed along the coast, then

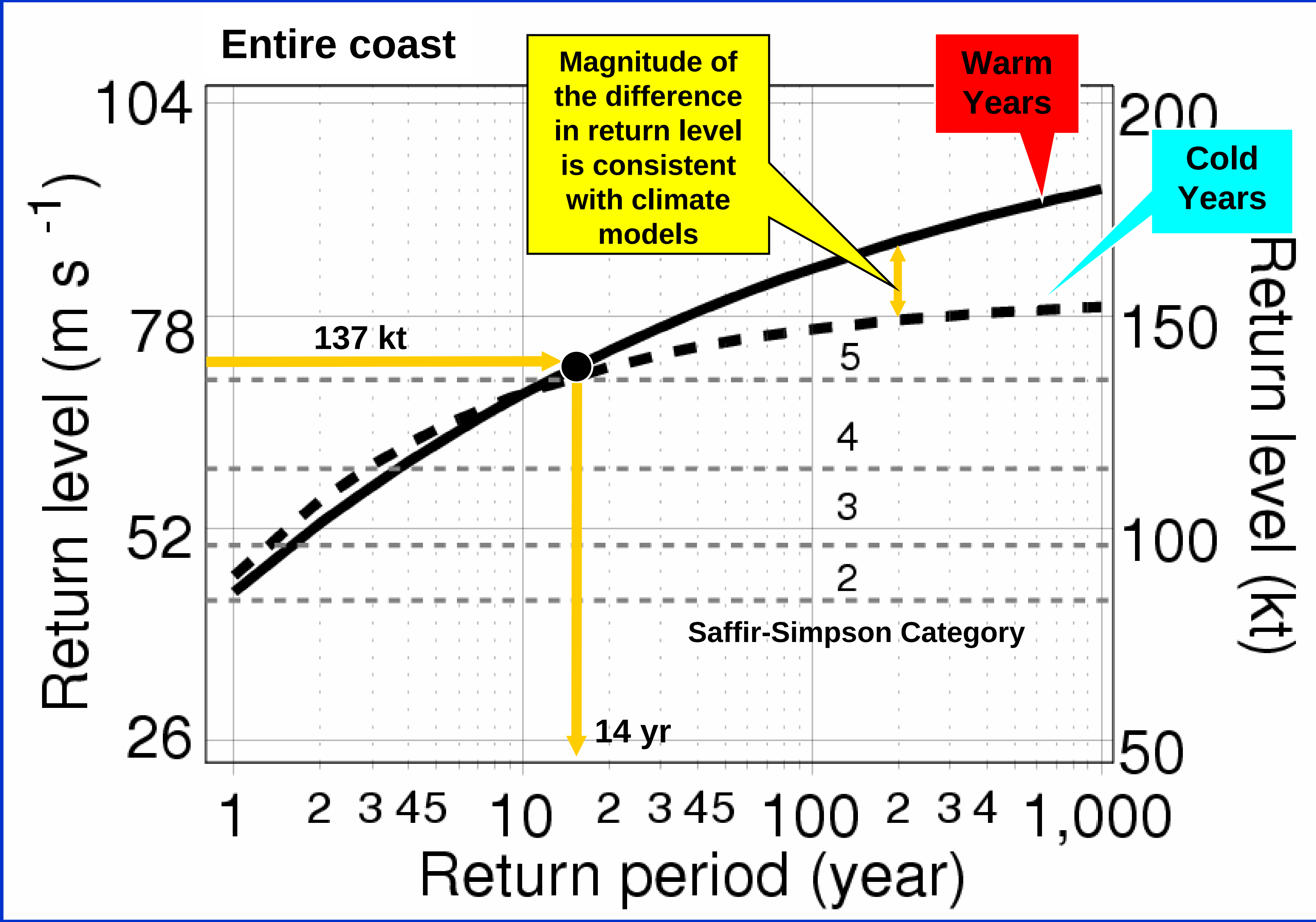
$$P(x > v | x > u) = \begin{cases} \exp([v-u]/\tilde{\sigma}) & \text{for } \xi = 0, \\ (1 + \frac{\xi}{\tilde{\sigma}}[v-u])^{-1/\xi} & \text{for } \xi \neq 0, \end{cases}$$

where $\tilde{\sigma} = \sigma + \xi(u - \mu)$.

- Set $u = 64$ kt (1 kt $= 0.5$ ms$^{-1}$), $\sigma = 30$ kt, and $\mu = 100$ kt to obtain the following probability curves.




Gulf coast
Hurricane Katrina
95% Confidence Limit
104
78
52
26
Return level (m s -1)
200
150
100
50
Return level (kt)
137 kt
21 yr
Gulf coast
1 2 3 4 5 10 2 3 4 5 100 2 3 4 1,000
Return period (year)
Statistical model from extreme value theory; data 1899-2004


Entire coast
Magnitude of the difference in return level is consistent with climate models
Warm Years
Cold Years
104
78
52
26
200
150
100
50
Return level (m s -1)
Return level (kt)
137 kt
14 yr
5
4
3
2
Saffir-Simpson Category
1 2 3 4 5 10 2 3 4 5 100 2 3 4 1,000
Return period (year)

# Calibrating prehistoric overwash events

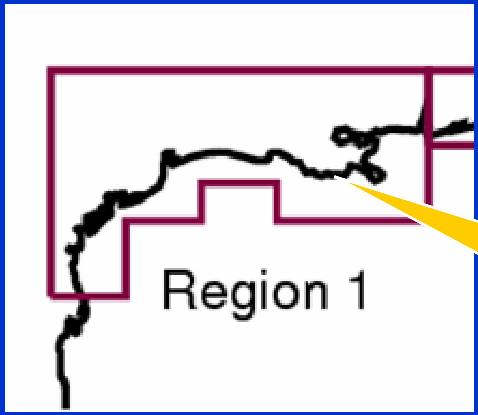
From the chronology of overwash events at the Atchafalaya Marsh (Site 3 on map) we find 10 events in 900 years.

The linear storm extent of these events is estimated to be 150 km.

The historical wind speed model uses historical hurricane winds from Brownsville TX to the FL/AL (Gulf coast; Region 1 on map) border to estimate return levels and associated return periods.  The coastline distance is estimated to be 1500 km or 10x that of the linear storm extent.

Assuming uniformity of events over space, we multiple the 10 events by 10 to get 100 events in the Gulf coast region. The return period is thus 900/100 =  9 yr.

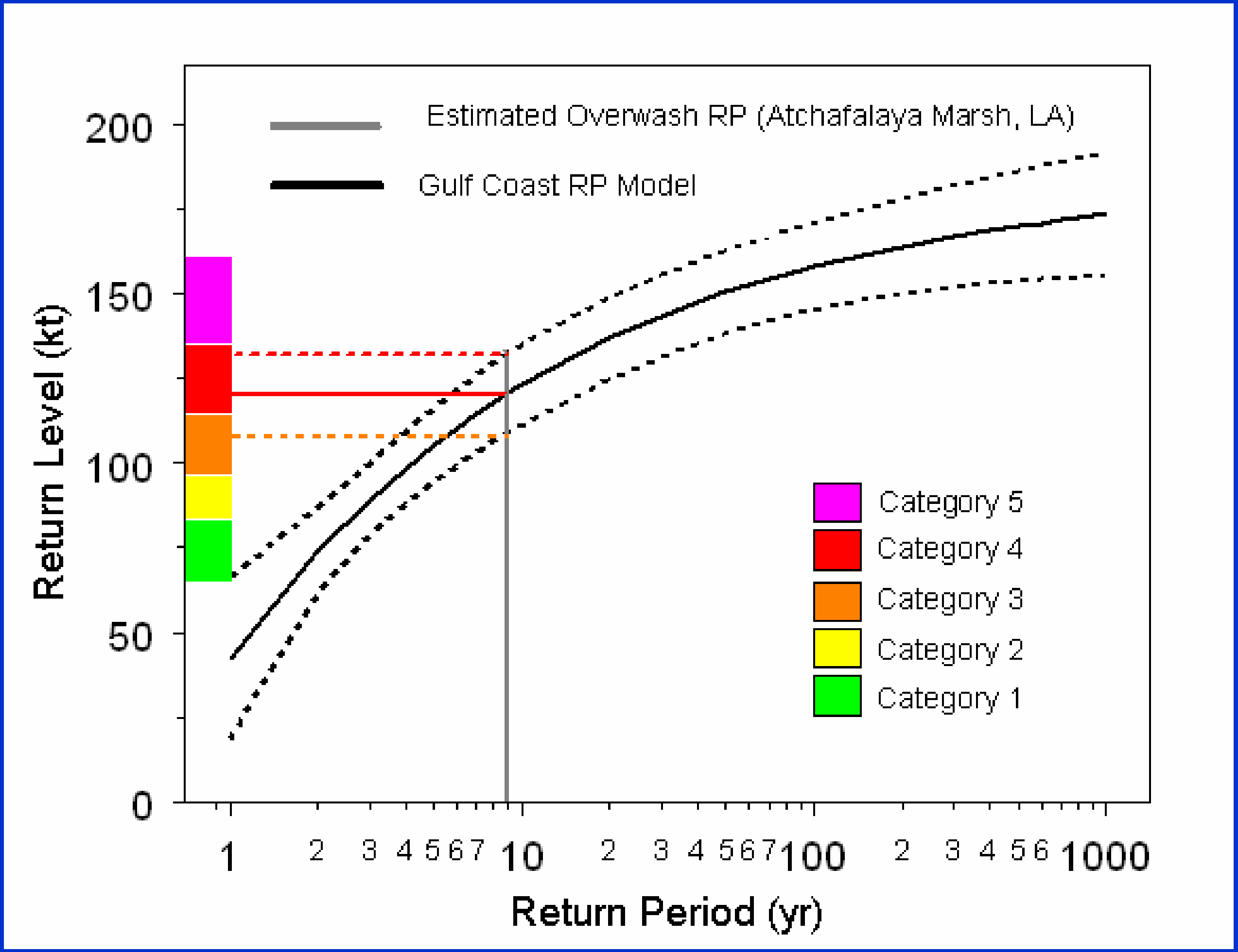

Atchafalaya Marsh Study Site



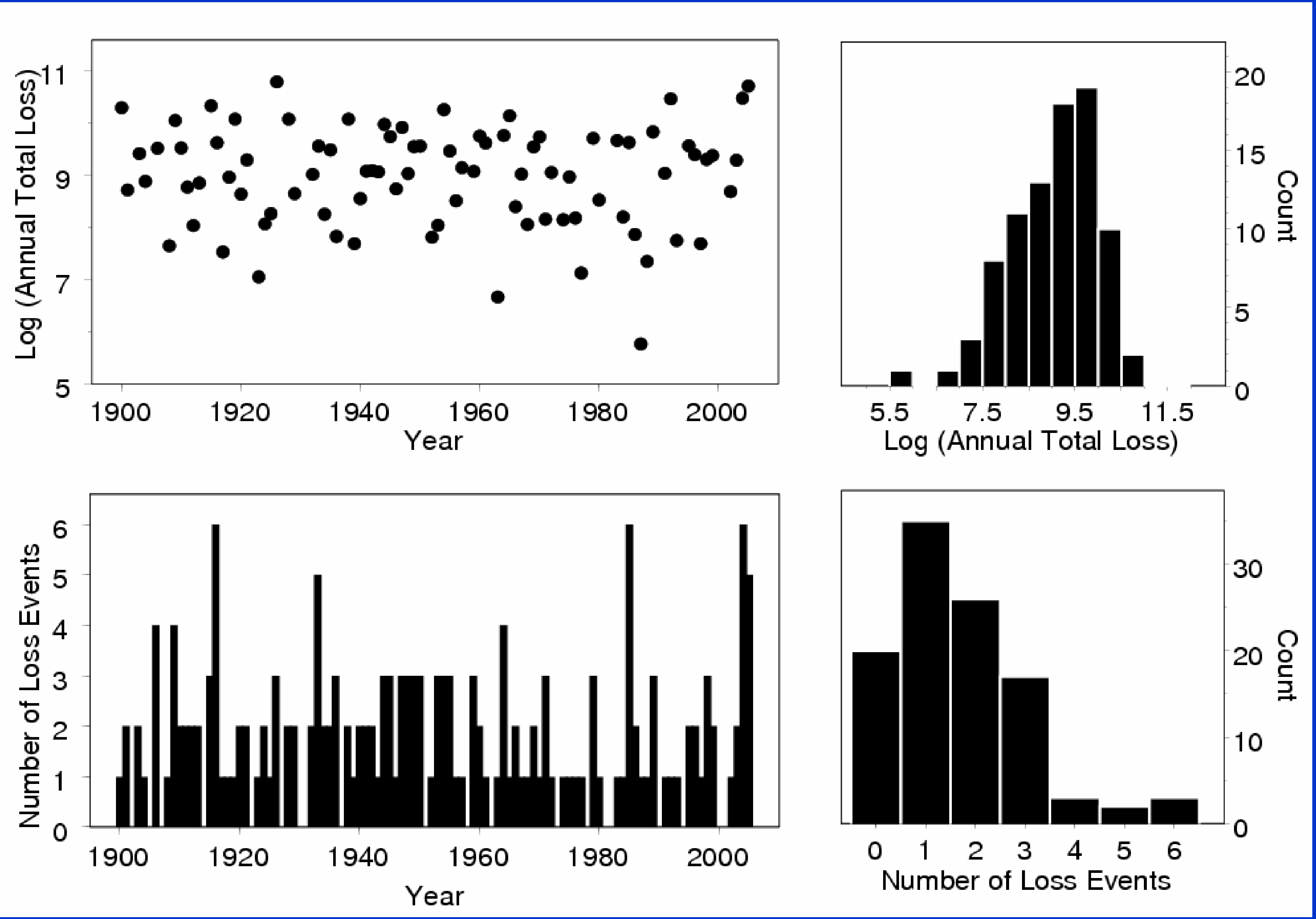

1500 km of coastline

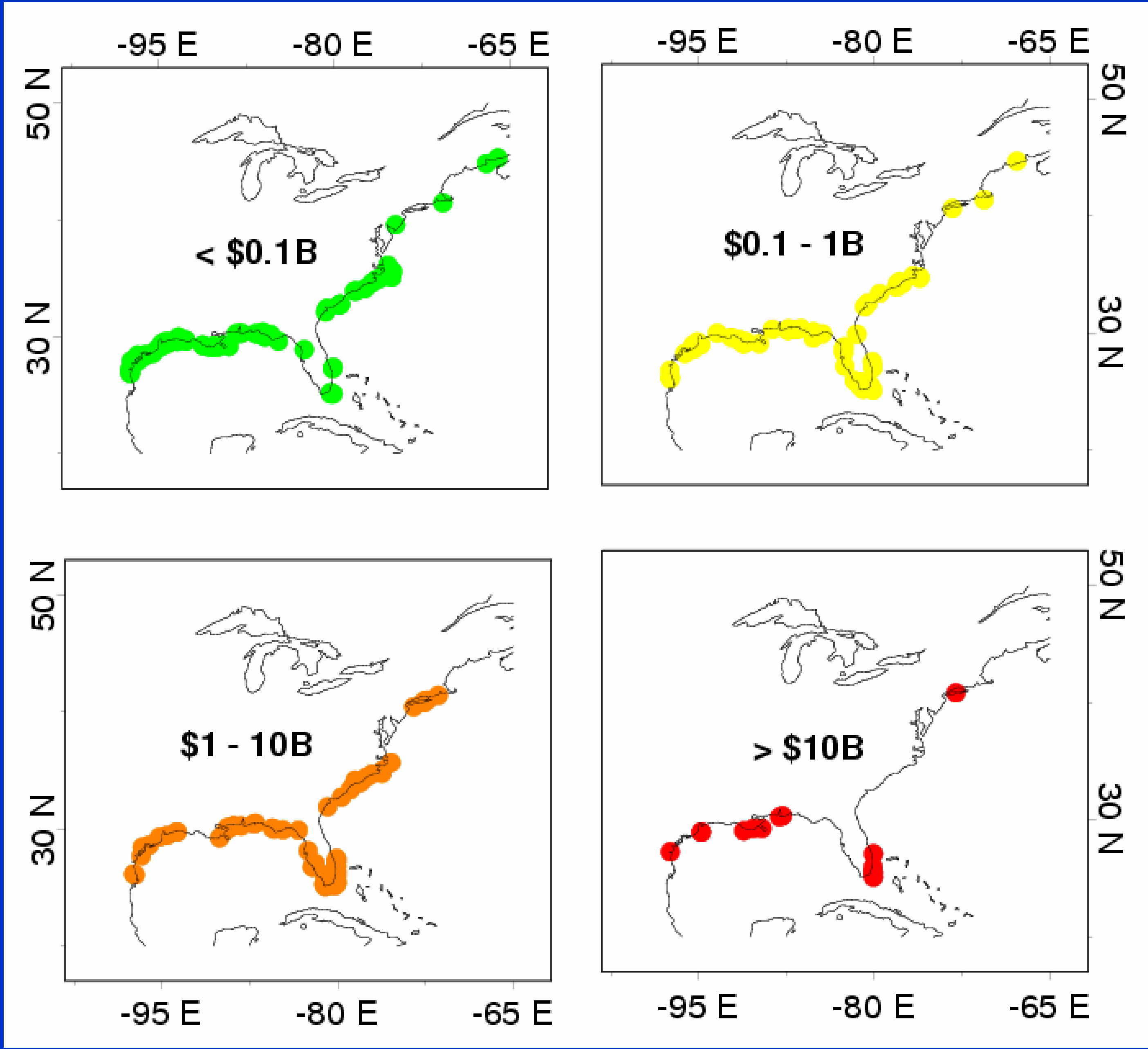
# Calibration results

The return period of 9 years is plotted as the vertical grey line and corresponds to winds in the category 4 range using the historical wind speed model.

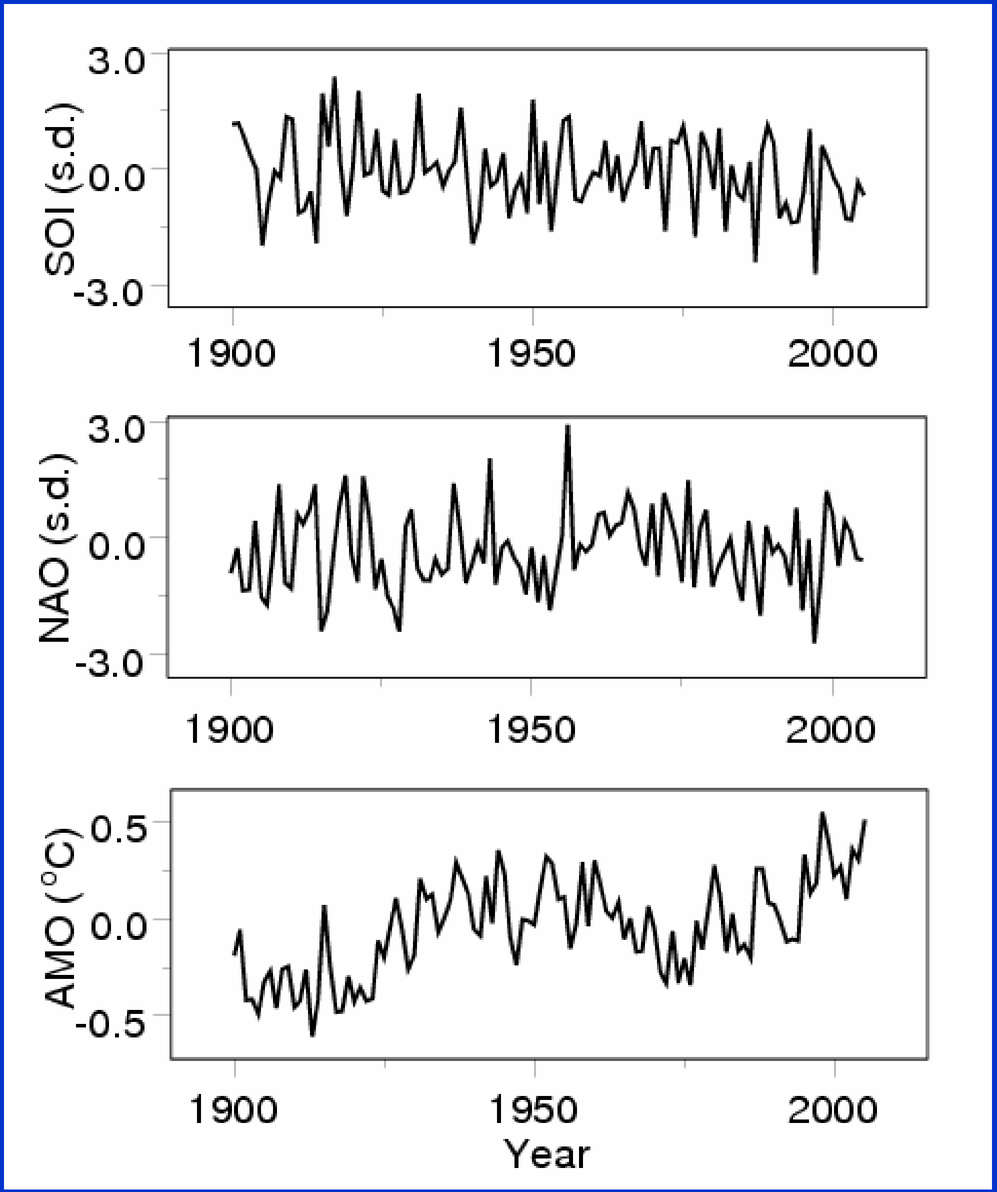


# Forecasting insured losses

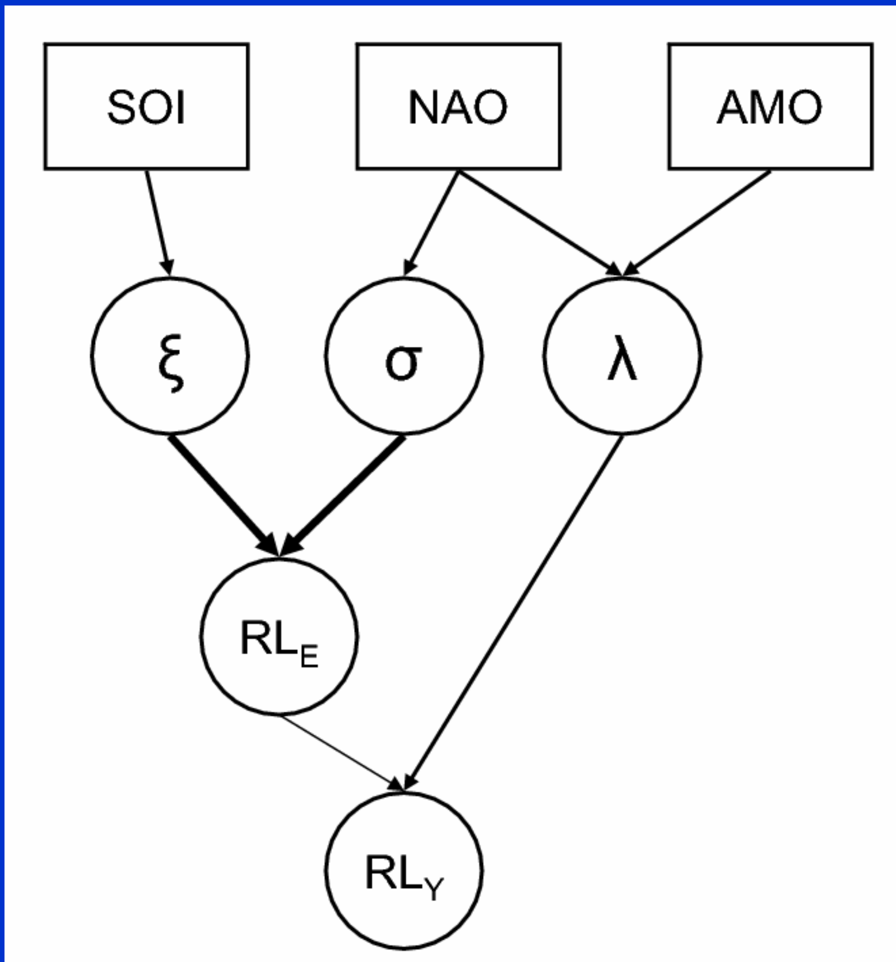


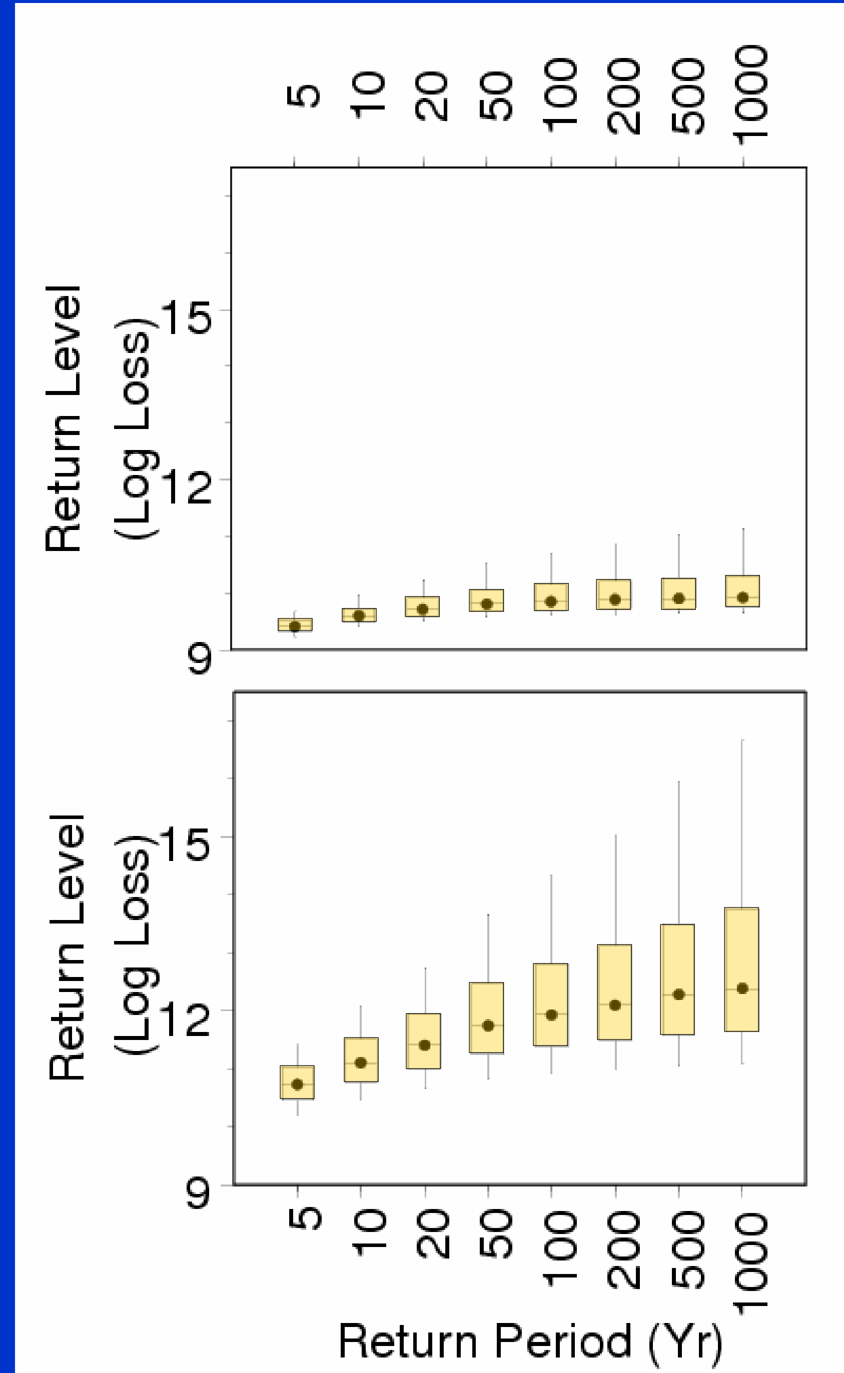


-95 E
-80 E
-65 E
50 N
30 N
< $0.1B
$0.1 - 1B
$1 - 10B
> $10B



3.0
SOI (s.d.)
0.0
-3.0
1900
1950
2000
3.0
NAO (s.d.)
0.0
-3.0
1900
1950
2000
0.5
AMO (°C)
0.0
-0.5
1900
1950
2000
Year


SOI
NAO
AMO
ξ
σ
λ
RL$_E$
RL$_Y$


Return Level (Log Loss)
9
12
15
5
10
20
50
100
200
500
1000
Return Period (Yr)

# Summary

- Taken as a random event along the Gulf coast, the return period of Hurricane Katrina is 21 years.
  - Katrina might be a harbinger of things to come as the observed and modeled effect of global warming appears to start at Katrina’s intensity.

# Summary

- Preseason climate signals provide information as to the character of the upcoming hurricane season.
  - Insured losses (both expected and maximum) show a statistical link to the preseason climate signals.

# More Information

- Google hurricane climate
- http://garnet.fsu.edu/~jelsner/www
- jelsner@fsu.edu