Impact of Climate Change on the National Flood Insurance Program

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CLIMATE CHANGE

Financial Risks to Federal and Private Insurers in Coming Decades are Potentially Significant

Statement of John B. Stephenson, Director
Natural Resources and Environment

GAO
Accountability * Integrity * Reliability

GAO-07-820T

- **Recommends FEMA analyze the potential long-term implications of climate change on the NFIP and report the findings to Congress.**
- **FEMA should use assessments from CCSP and IPCC**

Climate Change Study

- **AECOM, in association with Michael Baker Jr,. and Deloitte, conducted the study**
- **Study initiated September 2008**
- **Study scheduled to be released early 2012**
- **Climate Change impact on NFIP—aspects being investigated:**
  - Changes in precipitation patterns
  - Changes in frequency and intensity of coastal storms
  - Changes in sea levels

Why is Climate Change important to NFIP?

- **NFIP currently has:**
  - **5.6 million policies in force**
  - **$1.2 trillion coverage in force**
  - **$18 billion debt to U.S. Treasury**

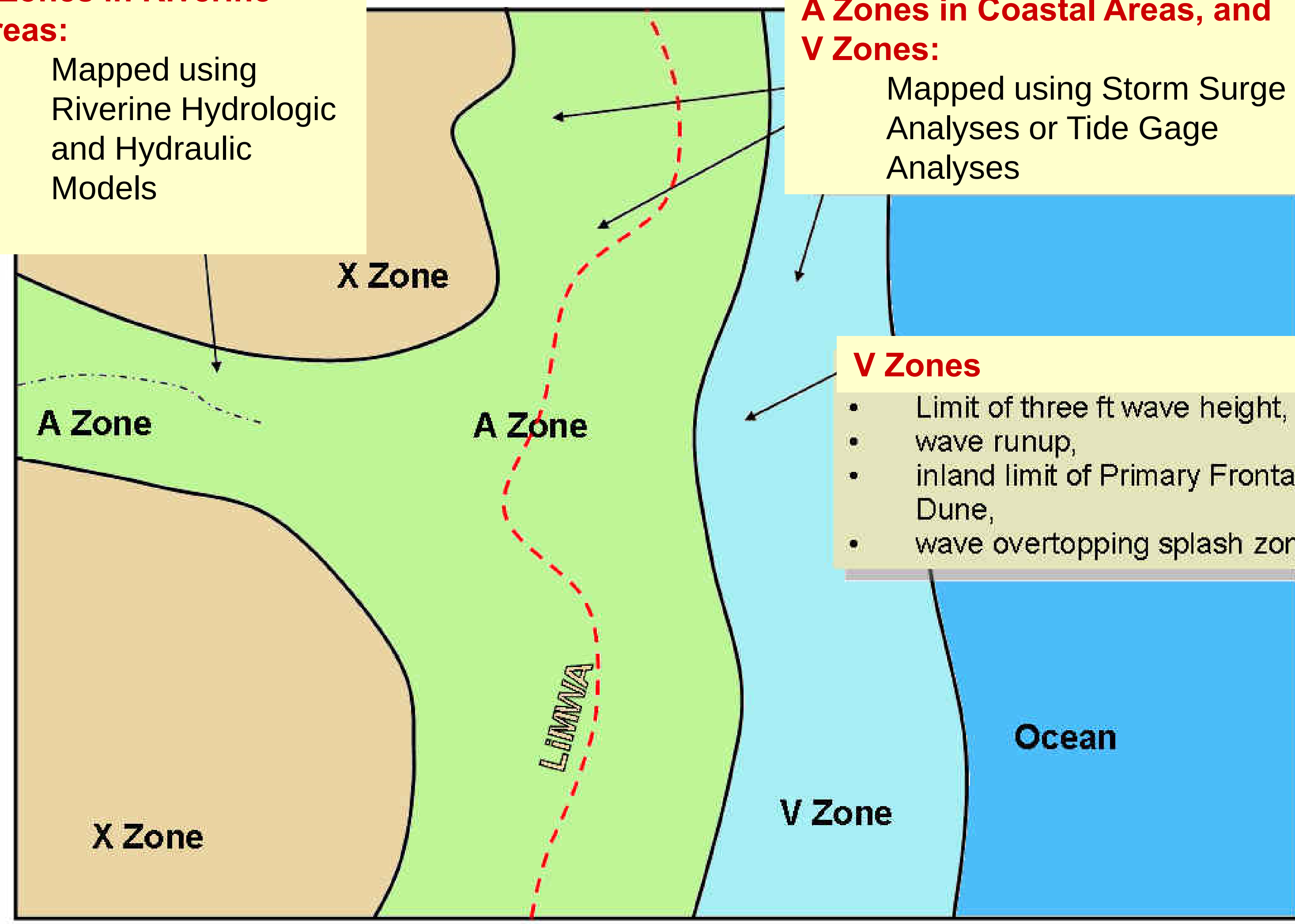
FEMA Flood Zones

A Zones in Riverine Areas:

Mapped using Riverine Hydrologic and Hydraulic Models

A Zones in Coastal Areas, and V Zones:

Mapped using Storm Surge Analyses or Tide Gage Analyses



V Zones

- Limit of three ft wave height,
- wave runup,
- inland limit of Primary Frontal Dune,
- wave overtopping splash zone

Loss and Expense Experience
Three Loss Periods

	Loss Period		
	1986-2003	1986-2007	1986-2008 (incl. Katrina)
Total Actuarial Policies:	$496,000,000	($12,119,000,000)	($13,217,000,000)
• V Zones	$141,000,000	$136,000,000	$133,000,000
• A Zones	$821,000,000	($7,890,000,000)	($8,469,000,000)
• X Zones	($467,000,000)	($4,365,000,000)	($4,881,000,000)
Program Total	$64,000,000	($17,902,000,000)	($20,004,000,000)

(Actuarial and subsidized policies)

(Program Total currently shows $17,750,000,000 loss)

Climate Change not Directly Considered in the NFIP

- **But SLR is considered <u>indirectly</u> to the extent that:**
  - **Contingency loading—SLR (unquantified)**
  - **Long-term erosion (a consequence of sea level rise) is discussed in Coastal Construction Manual**
  - **NFIP Community Rating System gives credits towards freeboard and long-term coastal erosion-based setbacks**
  - **Insurance rates in V Zones consider effects of long-term erosion**

What Has FEMA Done in Past to Address Climate Change?

- **1991: FEMA completed Congressionally mandated study on impact of sea level rise on NFIP**
  - **Study titled: "Projected Impact of Relative Sea Level Rise on the National Flood Insurance Program"**
  - **Mandated by Congress in 1989**
  - **Managed by Mike Buckley & Howard Leikin**
  - **Completed in 1991**
  - **Study used findings from 1990 IPCC report, EPA reports, and other peer-reviewed papers**

1991 Sea Level Rise Study

- **Examined 3 sea level rise scenarios over period from 1990 to 2100**
  - No change
  - One-foot rise over the next century
  - Three-foot rise over the next century

1991 Sea Level Rise Study: Conclusions (1)

- **For the 1-foot projection the NFIP would not be significantly impacted for the following reasons**
  - New construction in coastal areas often built more than one foot above BFE
  - Aspects of flood insurance rate making already account for the possibility of risk
  - Insurance rates could be adjusted to reflect new risk information
- **For the 3-foot projection the incremental increase of the first foot would not be expected until 60 years later, which would allow time for NFIP to consider alternate approaches to loss control, insurance mechanisms**

1991 Sea Level Rise Study: Conclusion (2)

- **However the report noted that possibility exists for significant impacts in the long-term, therefore FEMA should:**
  - **Monitor progress in scientific community regarding SLR**
  - **Strengthen efforts to monitor development trends and incentives of the Community Rating System that encourage measures which mitigate the impacts of SLR**

What else has FEMA Done in Past to Address Climate Change?

- **Long-term Coastal Erosion**
  - FEMA has long history dealing with long-term coastal erosion issue as it impacts NFIP
  - Long-term coastal erosion is a consequence of sea level rise
  - 1990 NRC recommended long-term erosion mapping, insurance, and land-use requirements should be incorporated into NFIP
  - NRC report stimulated Congressional interest
  - Bills introduced requiring FEMA to consider long-term erosion within NFIP
  - Opposition to these Bills from special interest groups

Long-Term Coastal Erosion

- **Long-term Coastal Erosion**
  - Section 577 of NFIRA of 1994 requires FEMA to conduct economic impact analysis of erosion mapping
  - Heinz Center conducts erosion study. Study is released in 2000 and recommends that Congress instruct FEMA to map long-term erosion hazard areas and use this information to modify insurance rates to reflect long-term erosion hazard
  - Congress has not acted on these recommendations
  - Under existing authorities that govern NFIP, FEMA increased V Zone rates close to 10-percent maximum most years between 2001 and 2009

Impact of Climate Change on the NFIP: Study Objectives

- **Objectives of the current study are to quantify the impacts of climate change, including changes in precipitation patterns, coastal storms, sea level rise, etc. on the:**
  - Location and extent of the U.S. floodplains
  - Relationship between the elevation of insured properties and the 100-year BFEs, and
  - Economic structure of the NFIP.
- **Looking at 90-yr timeframe, with 20-yr intervals**
- **Using probabilistic approach rather than a scenario-based approach**

[BFE – Base Flood Elevation]

Key Project Staff

- **AECOM**
  - Scott Edelman, Principal
  - Perry Rhodes, Project Manager
  - David Divoky, Project Lead and Principal Author
  - Manas Borah, Assistant Project Manager
  - Art Miller
  - Kevin Coulton
  - Josh Kollat
  - Joe Kasprzyk
- **Michael Baker Jr. Inc.**
  - Will Thomas
  - Steve Eberbach
  - Senanu Agbley
- **Deloitte Consulting, LLP**
  - Susan Pino
  - Joshua Merck

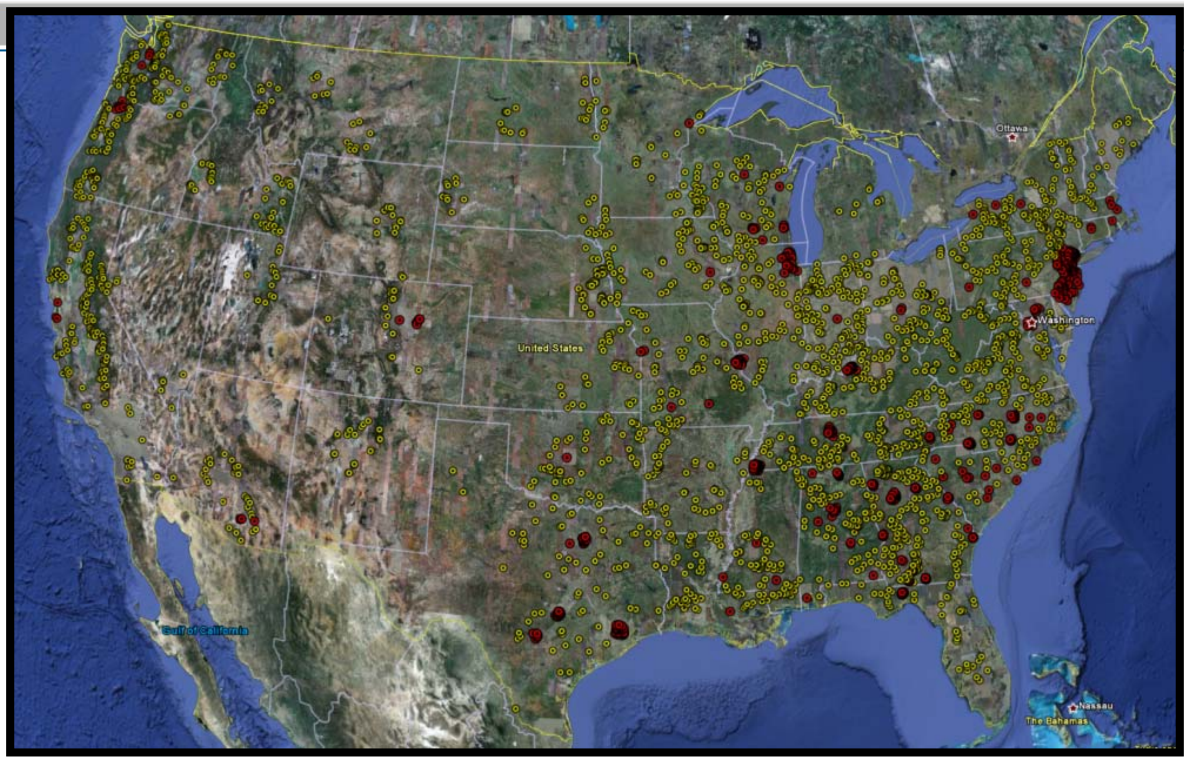
Review Panel Members

- **Margaret Davidson/Maria Honeycutt,** NOAA, CSC
- **David Levinson,** NOAA, NCDC
- **Kate White,** USACE
- **Howard Leikin,** retired, formerly Terrorism Risk Insurance, US Dept. of Treasury
- **Tony Pratt,** State of Delaware
- **Robert Dean,** Professor Emeritus, University of Florida
- **William Gutowski,** Iowa State University.

Impact of Climate Change on the NFIP: Riverine Analysis

- **Objective of riverine portion of analysis:** **develop regression equations that relate flood discharges to watershed characteristics and climate change indicators so that projections can be used to estimate future changes in flood discharges.**

Gage Identification



- Identified Urban and Rural Stations – from published USGS reports
  - Quality control resulted in 2357 usable gages
- This data provided DA, SL, ST, IA, and Existing $Q_{10\%}$ and $Q_{1\%}$

Impact of Climate Change Riverine Analysis: Controlling Parameters

- **Identify parameters (climate change indices in red) that control runoff**
  - Drainage Area
  - Average slope of stream
  - Storage capacity
  - Impervious area
  - Mean number of frost days
  - Mean number of consecutive dry days
  - Mean of the maximum 5-day rainfall

Climate Change Indices

Indicator	Description	Units
FD	Total number of frost days, defined as the annual total number of days with absolute minimum temperature below 0 deg C	days
GSL	Growing season length, defined as the length of the period between the first spell of five consecutive days with mean temperature above 5 deg C and the last such spell of the year	days
Tn90	Warm nights, defined as the percentage of times in the year when minimum temperature is above the 90th percentile of the climatological distribution for that calendar day.	%
R10	Number of days with precipitation greater than 10mm.	days
CDD	Maximum number of consecutive dry days.	days
R5d	Maximum 5-day precipitation total.	mm
SDII	Simple daily intensity index, defined as the annual total precipitation divided by the number of wet days.	$mm\ d^{-1}$
R95T	Fraction of total precipitation due to events exceeding the 95th percentile of the climatological distribution for wet day amounts.	%

Regression Equations

- **Equations for entire U.S.**

$Q10 = 0.1093 \bullet DA^{0.723} \bullet SL^{0.158} \bullet (ST+1)^{-0.339} \bullet (IA+1)^{0.222}$

$\bullet (FD+1)^{-0.044} \bullet (CDD+1)^{-0.395} \bullet (R5D+1)^{1.812}$

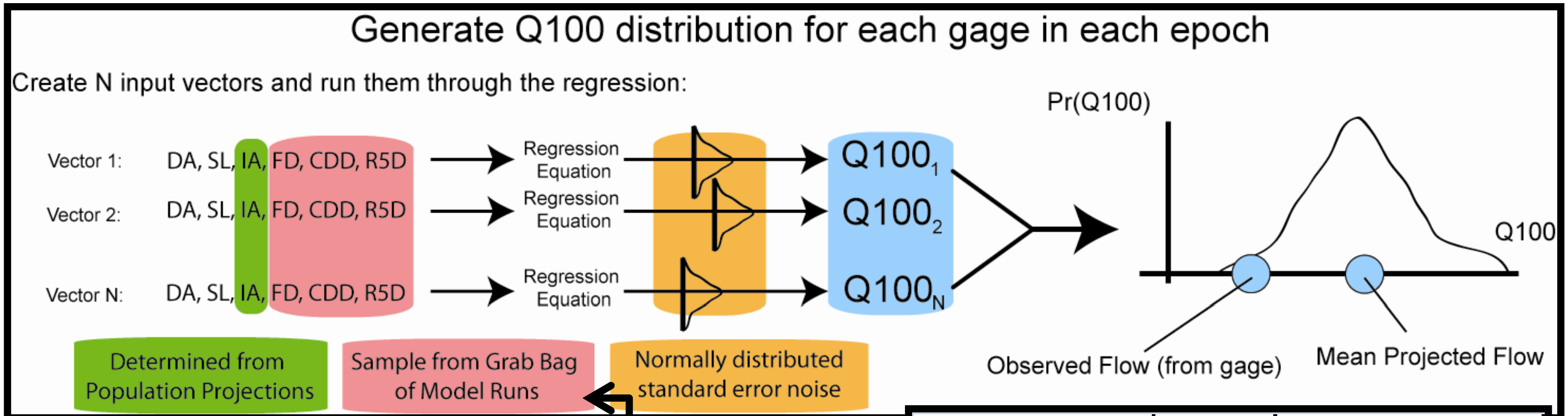
- **Standard Error: 0.2318 log units or 57.4%**
- **$R^2 = 0.906$**

$Q100 = 1.321 \bullet DA^{0.711} \bullet SL^{0.169} \bullet (ST+1)^{-0.332} \bullet (IA+1)^{0.188}$

$\bullet (FD+1)^{-0.206} \bullet (CDD+1)^{-0.177} \bullet (R5D+1)^{1.440}$

- **Standard Error: 0.2368 log units or 58.8%**
- **$R^2 = 0.898$**

Monte Carlo Analysis Procedure



Model	Country	Projections		
		B1	A1B	A2
CCSM3	USA	X	X	
CNRM-CM3	France	X	X	X
GFDL-CM2.0	USA		X	X
GFDL-CM2.1	USA		X	X
INM-CM3.0	Russia	X	X	X
IPSL-CM4	France	X	X	X
MIROC3.2 Hi Res	Japan	X	X	
MIROC3.2 Med Res	Japan	XX	XXX	XXX
MRI-CGCM2.3.2	Japan		XXXXX	X
PCM	USA	XXXX	XXXX	XXXX
Total		43		

- Uncertainty accounted for by sampling from:
  - Multiple models, runs, and scenarios
  - Standard error from the regression equation

Impact of Climate Change: Relating H&H Results to Insurance

- **Use projected increase in 1% discharge with FIS rating curves to estimate changes in:**
  - 1% chance water surface elevation
  - 1% chance water surface top width
- **Determine Insurance/Financial Impacts**
  - Overlay flood estimates with insurance/demographic data
  - Extend to estimate the national impact

[H&H: Hydrology and Hydraulics; FIS: Flood Insurance Study]

Important Literature: Riverine Analyses

- **Main resources of focus:**
  - **IPCC Summary for Policy Makers**
    - Excellent overview of climate change
  - **Riverine:**
    - **Alexander et al. (2005)** – *Global observed changes in daily climate extremes of temperature and precipitation*
    - **Tebaldi et al. (2006)** – *Going to Extremes: An Intercomparison of Model-Simulated Historical and Future Changes in Extreme Events*
  - **Population:**
    - **Bengtsson et al. (2006)** – *A SRES-based gridded population dataset for 1990-2100*
    - **Exum et al. (2006)** – *Estimating and Projecting Impervious Cover in the Southeastern United States*

Impact of Climate Change on the NFIP: Coastal Analysis

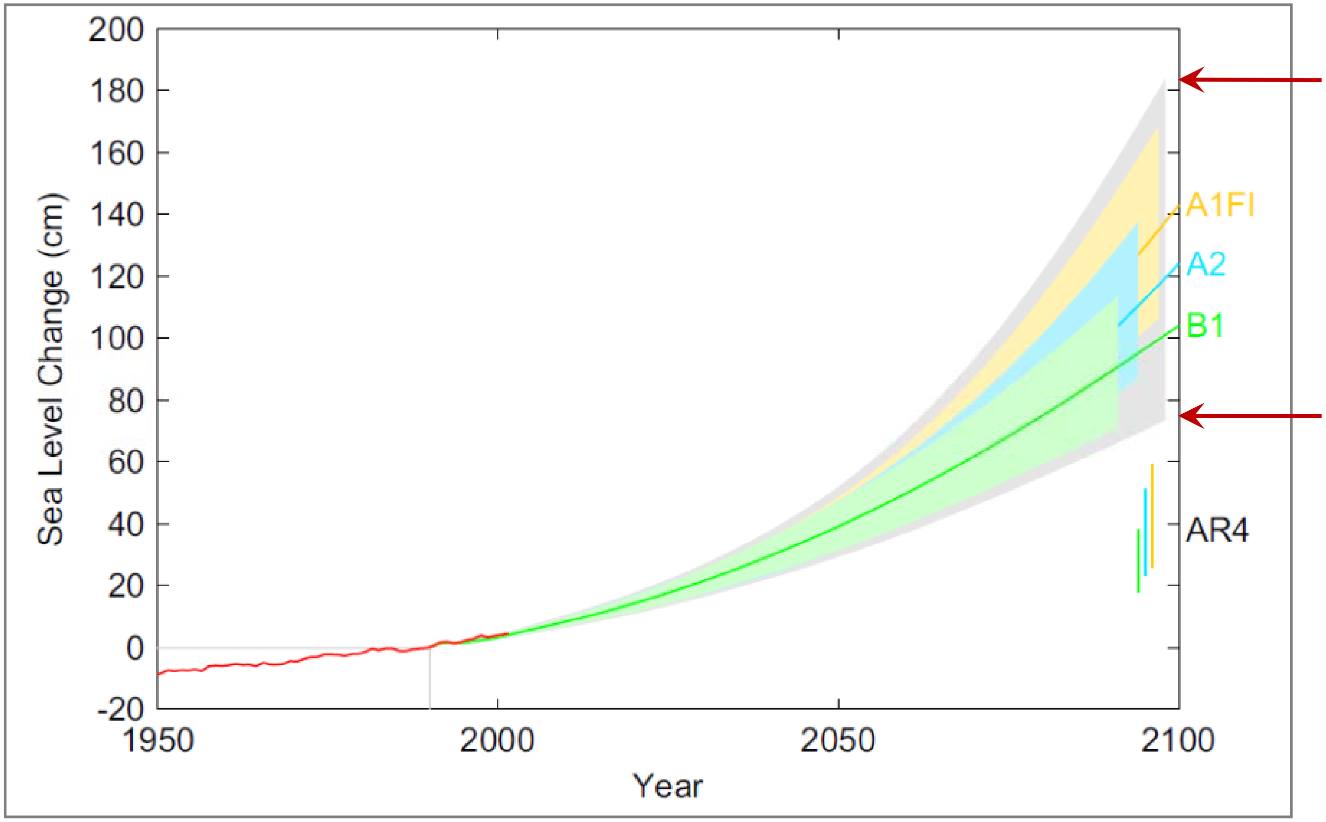
1. **Define Coastal Zones by Flood Source Type**
2. **Adopt IPCC/CCSP Estimates of Climate Factor Changes**
3. **Subdivide Zones into Common Areas for Analysis**
4. **Perform Monte Carlo Flood Response Simulations, considering change in frequency and intensity of coastal storms, and sea levels**
5. **Determine Insurance/Financial Impacts**

Key Coastal Research (besides IPCC and CCSP) Being Used in Study

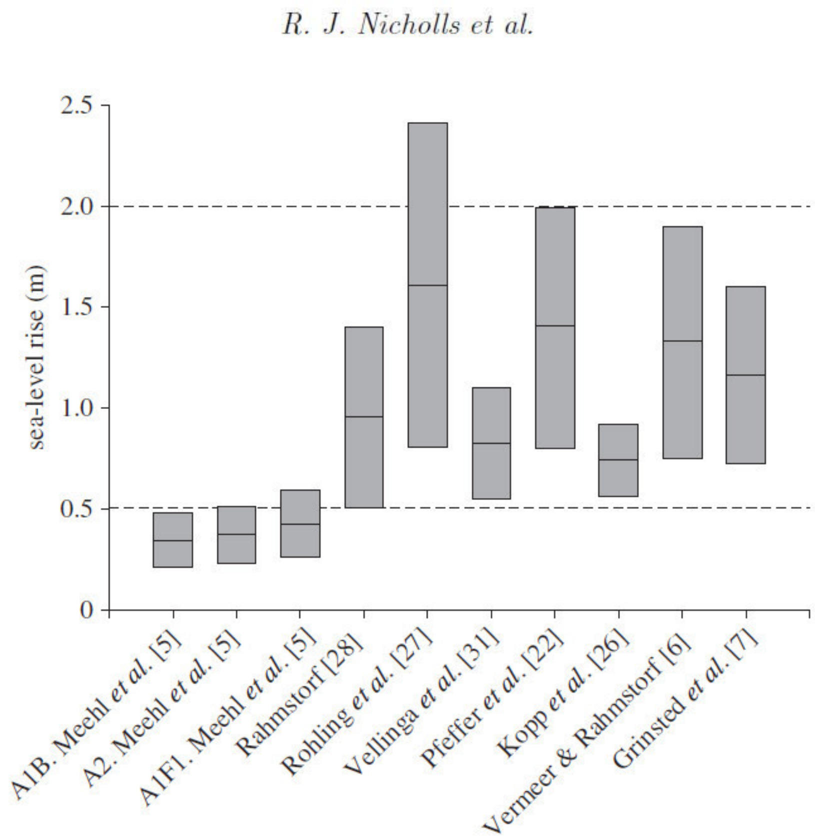
- **Sea Level Rise/Long-term Coastal Erosion**
  - Hammar-Klose & Thieler (2001) – USGS Coastal Vulnerability Index
  - Martin Vermeer, and Stefan Rahmstorf, 2009: *Global sea level linked to global temperature*, Proceedings of the National Academy of Sciences
- **Hurricanes and Tropical Storms**
  - Thomas R. Knutson, et al., 2010: *Tropical cyclones and climate change*, Nature Geoscience
  - Morris A. Bender, et al., 2010: *Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes*, Science
- **Extratropical Storms**
  - Lambert, S. and J.C. Fyfe, 2006: *Changes in winter cyclone frequencies and strengths simulated in enhanced greenhouse gas experiments: Results from the models participating in the IPCC diagnostic exercise,* Climate Dynamics
  - Bengtsson, et al., 2009: *Will Extratropical Storms Intensify in a Warmer Climate?* Journal of Climate

Sea Level Rise – Global Projections

- **Vermeer and Rahmstorf (2009): 0.75 to 1.9m for the period 1990 to 2100 (including +/- one σ)**



Variability in SLR Predictions

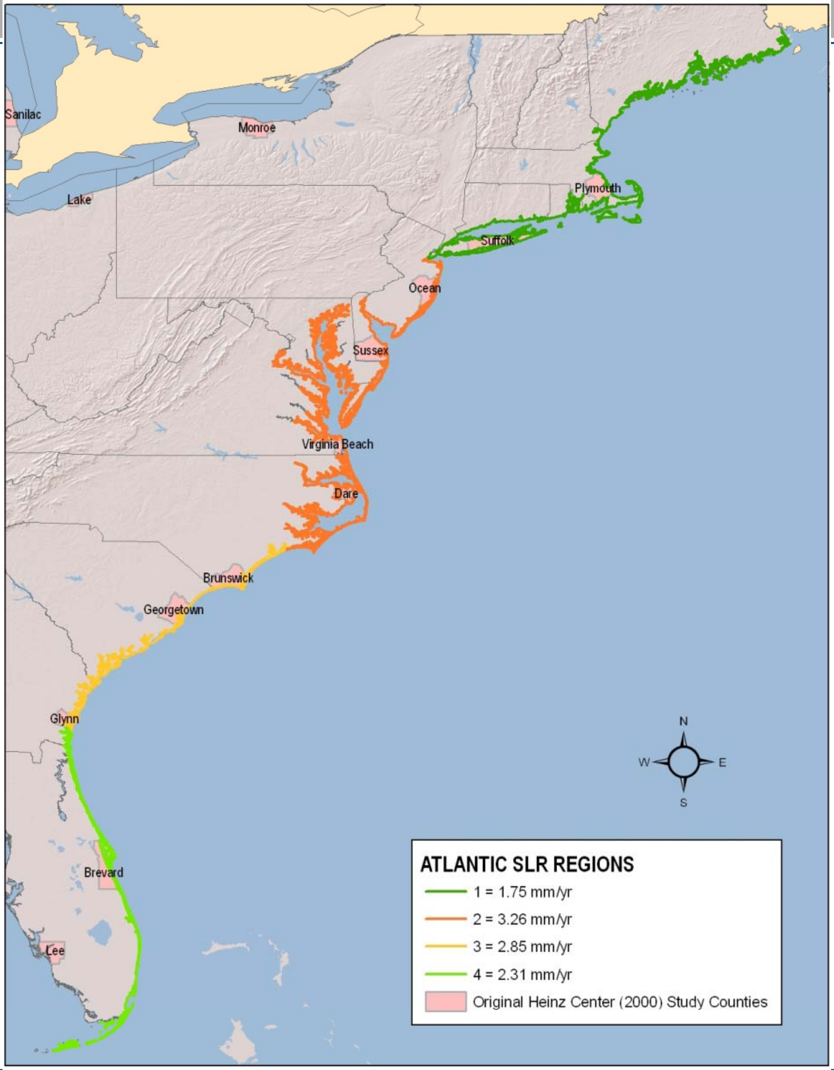


Meehl et al: 2007
Rahmstorf: 2007
Rohling, et al: 2008
Velinga, et al: 2008
Pfeffer, et al: 2008
Kopp, et al: 2009
Vermeer and Rahmstorf: 2009
Grinsted, et al: 2009

From Nicholls (2011):
"The range of future climate-induced sea-level rise remains highly uncertain…"

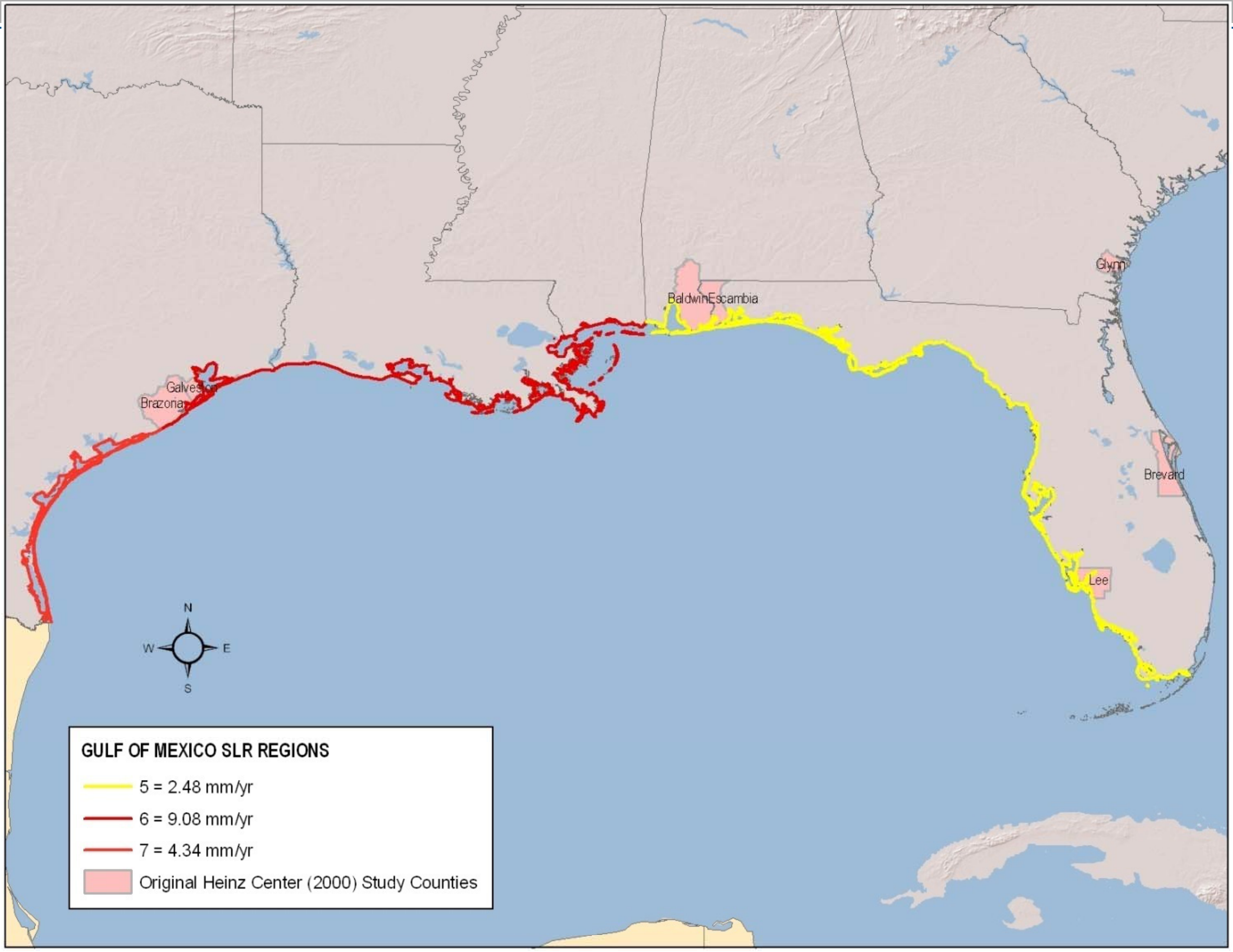
Sea Level Rise - Regionalization

- **4 Atlantic Coast SLR Regions**
- **Extratropical Storm Dominated: Region 1**
- **Tropical Storm Dominated: Regions 2-4**



Sea Level Rise - Regionalization

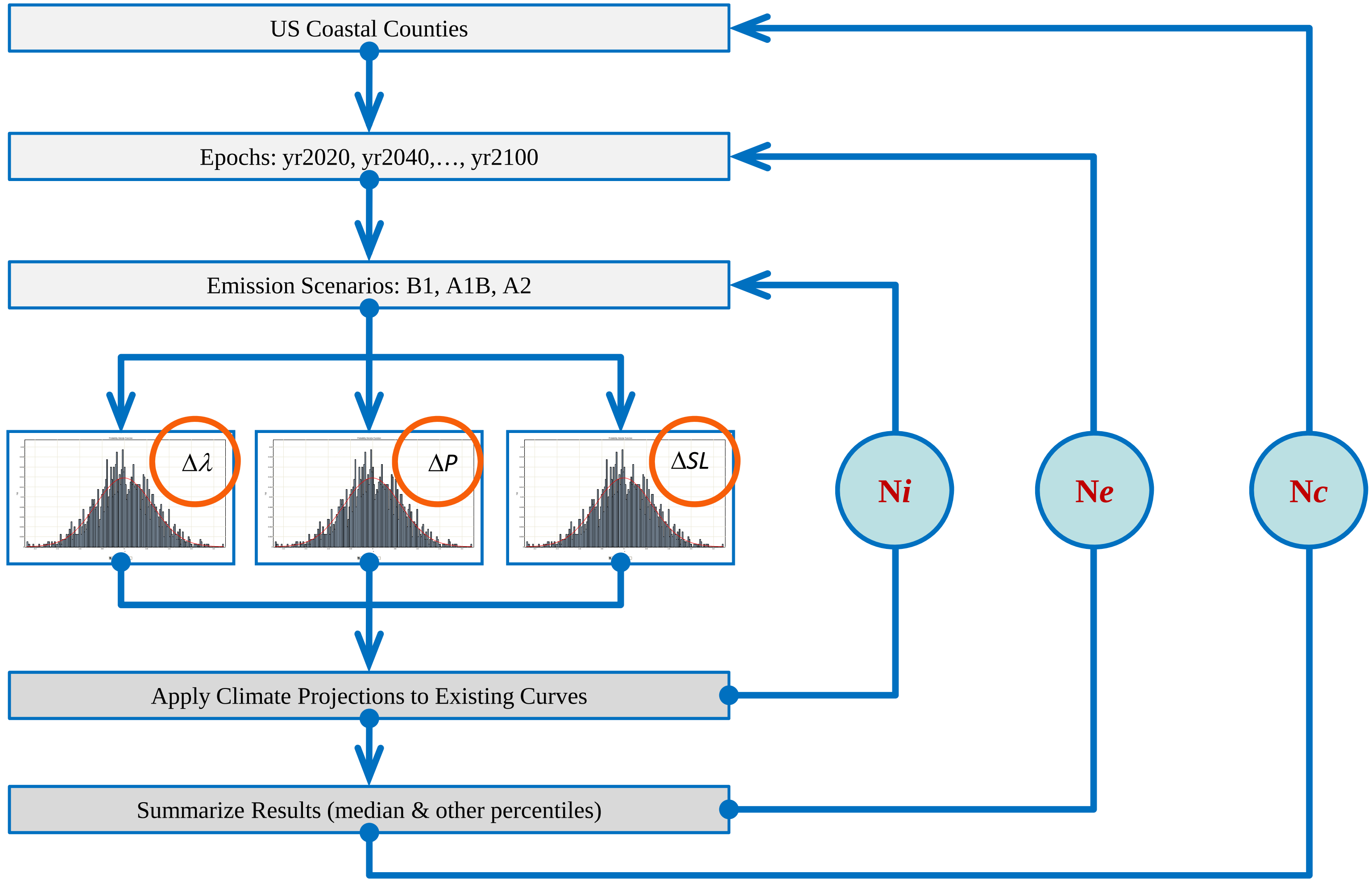
- **3 Gulf Coast Regions**
- **Tropical Storm Dominated: Regions 5-7**



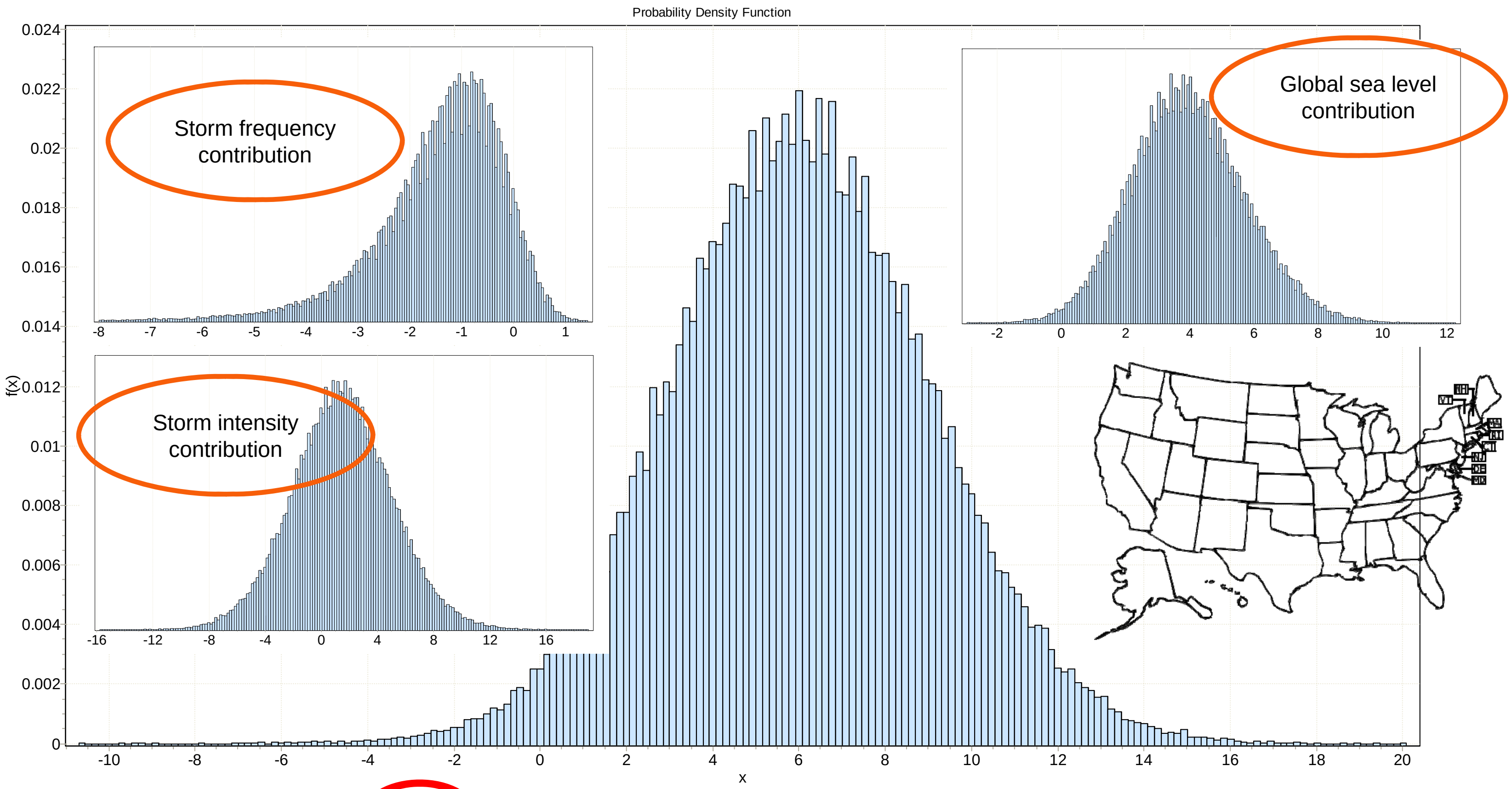
Sea Level Rise - Regionalization

- **3 Pacific Coast Regions**
- **Mixed Storms: Region 8**
- **Extratropical Storm Dominated: Regions 9-10**

Monte Carlo Simulations



Sample Result



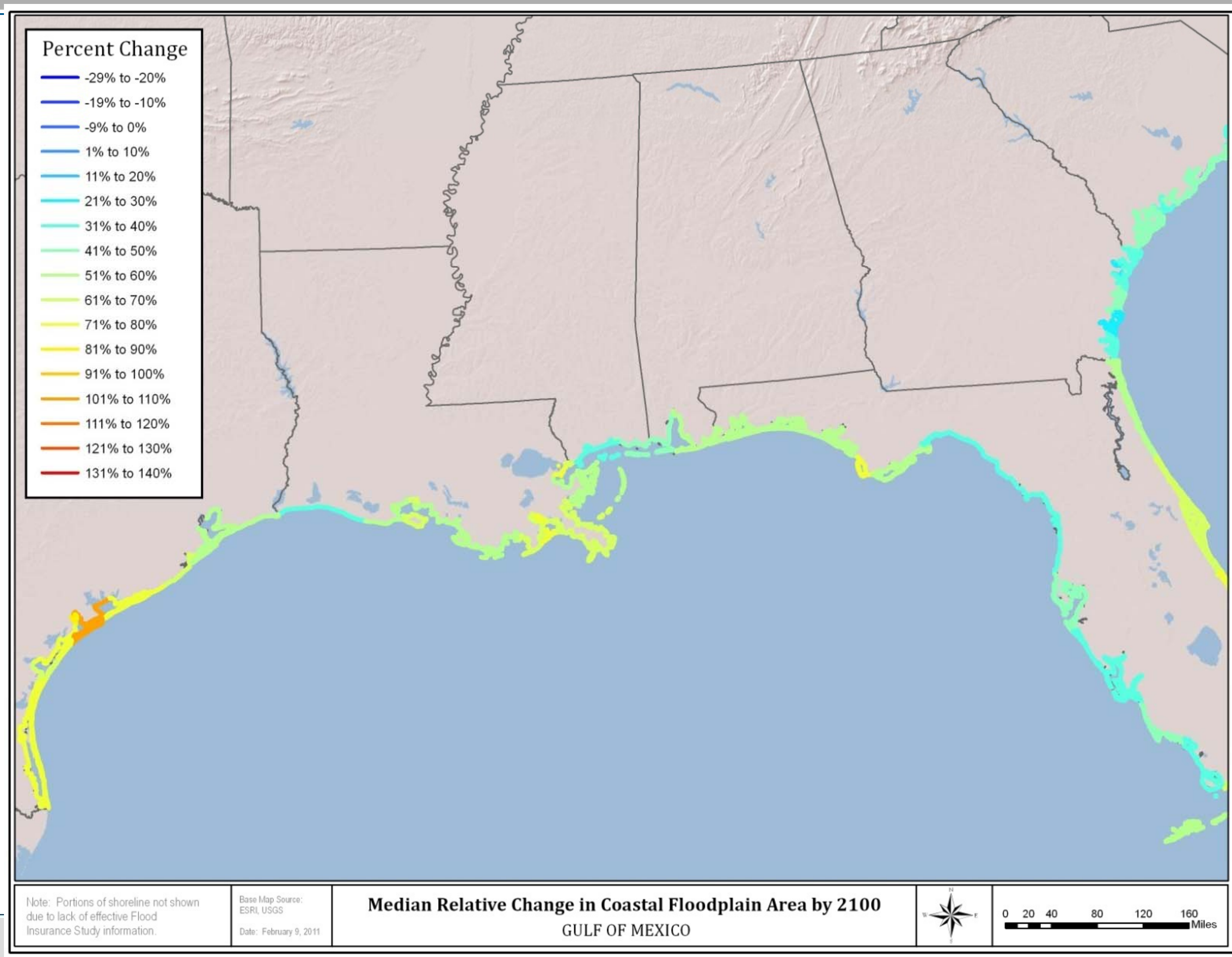
Change in 100yr Stillwater Elevation (feet; yr2100 – yr2000)

Scientific Findings

- **Riverine: By 2100 the 1% annual chance (100-yr) floodplain depth, and lateral size of riverine SFHAs, is projected to increase, on average, by about 45% across the Nation.**
  - **About 30% of these increases in floodplain area and flood depth may be attributable to normal population growth, while the remaining portion (70%) represents the influence of climate change.**
- **Coastal: By 2100 coastal SFHAs may increase anywhere from 0% to 55% (depending on type and scale of shore protection measures).**
- **Combined Riverine and Coastal: By 2100 the weighted nation-al average size of SFHAs may increase by about 40% to 45%.**

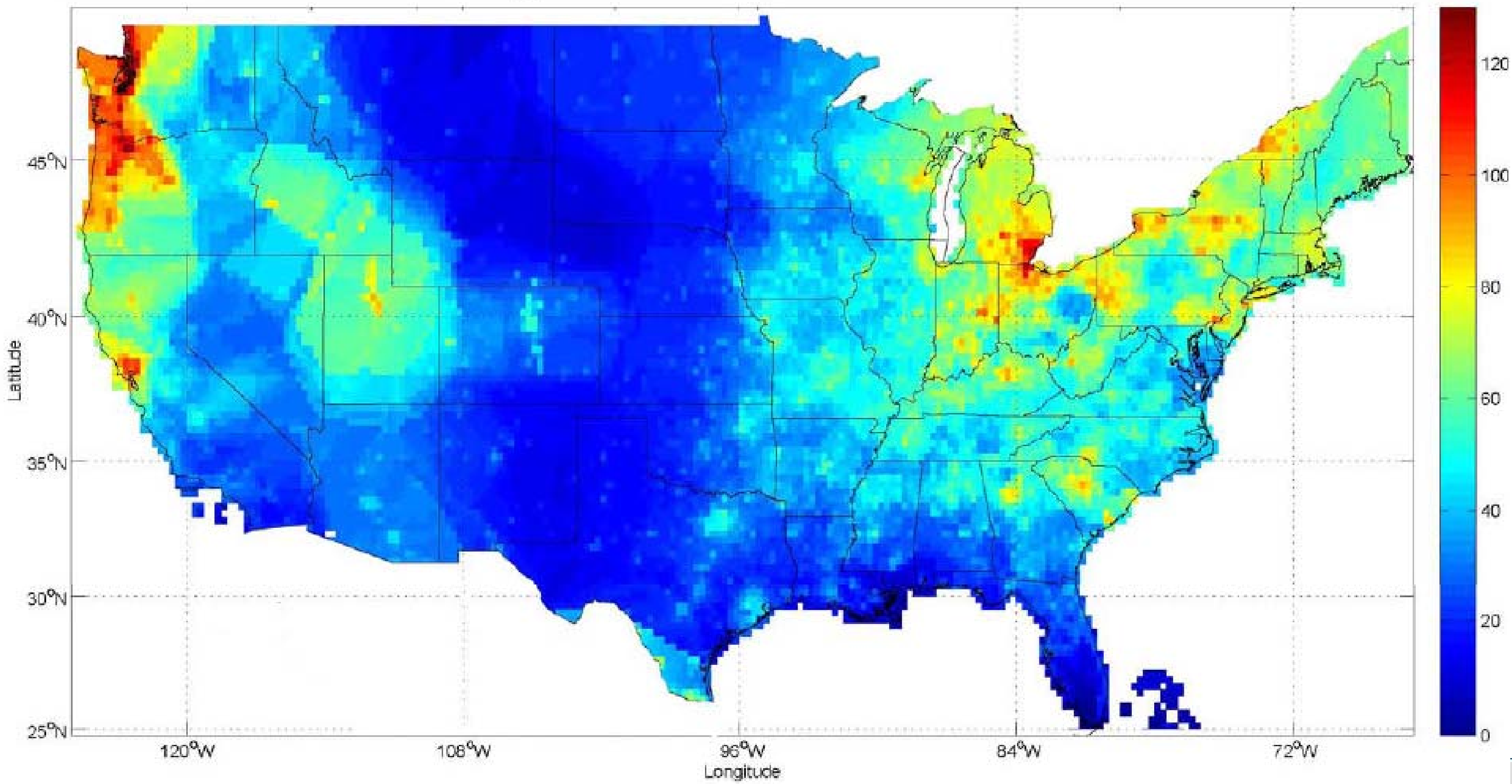
[SFHA – Special Flood Hazard Area]

Changes to Coastal Flood Hazard Areas: Gulf Coast



Changes to Riverine Flood Hazard Areas

Median Projected Percent Change in SFHA (i.e., 100-yr Flood) for 2100 over Current Conditions



Demographic/Economic Findings

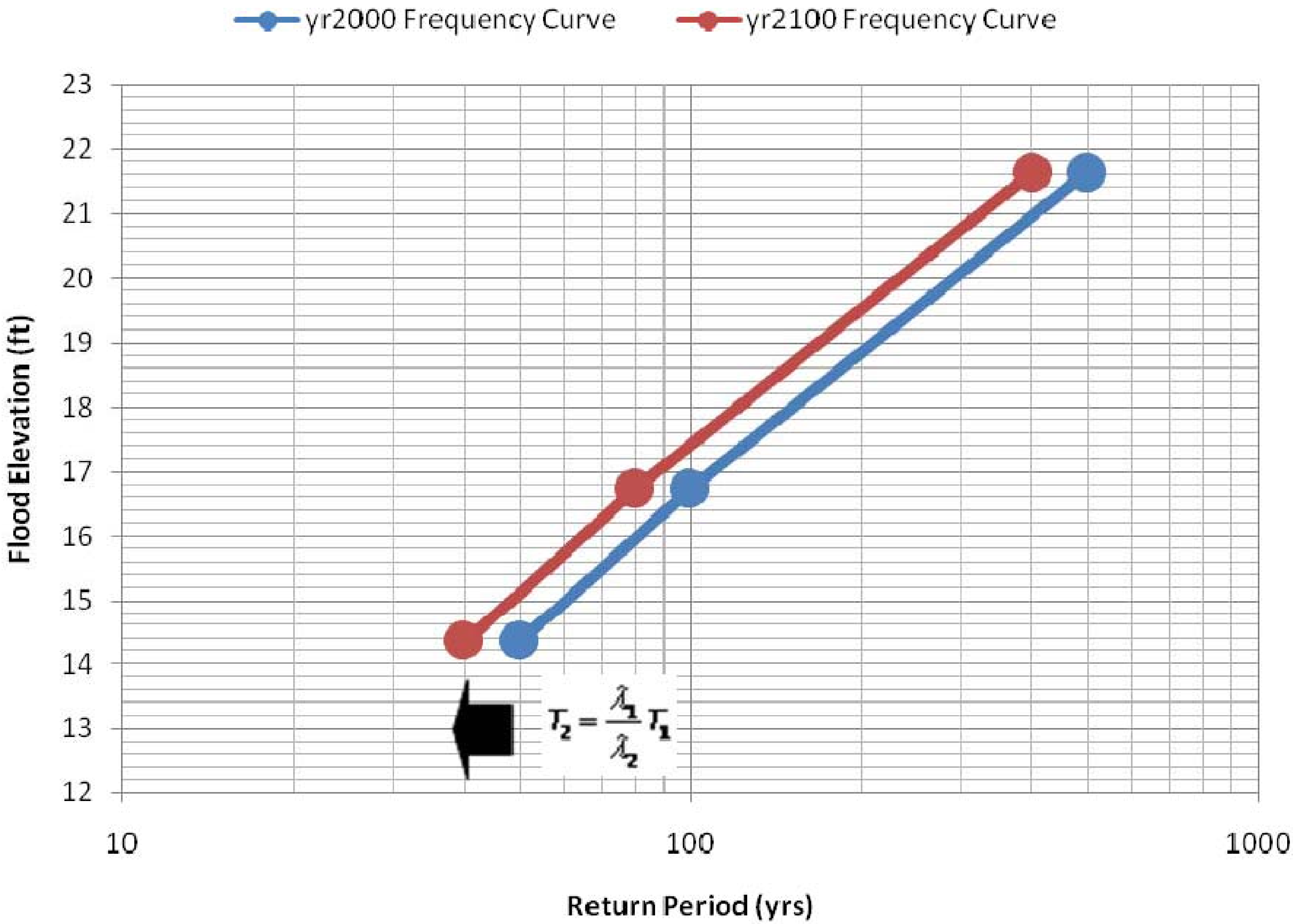
- **Combined Riverine and Coastal: By 2100 the weighted national average size of SFHAs may increase by about 40% to 45%.**
- **By 2100, <u>population</u> within riverine and coastal SFHAs will increase by approximately <u>130-155%</u>.**
- **Total <u>number of policyholders</u> participating in the NFIP is estimated to increase approximately <u>80-100%</u> cumulatively through the year 2100**
- **The <u>Average Premium Per Policy</u> will increase by about *10-70%* in today's dollars, because of the increase in flooding caused by climate change.**

Summary and Conclusions

- By 2100 the weighted national average size of riverine and coastal SFHAs may increase by about 40-45%.
- Even if future climate change is minimal, future flooding will increase anyway because: population growth→increase in development→increased impermeability →increased flooding.
- Because of increase in flooding and population, NFIP will continue to grow and by 2100 may insure almost double the number of policyholders as it does today.
- There is a need for FEMA to directly incorporate the effects of climate change into various aspects of the NFIP

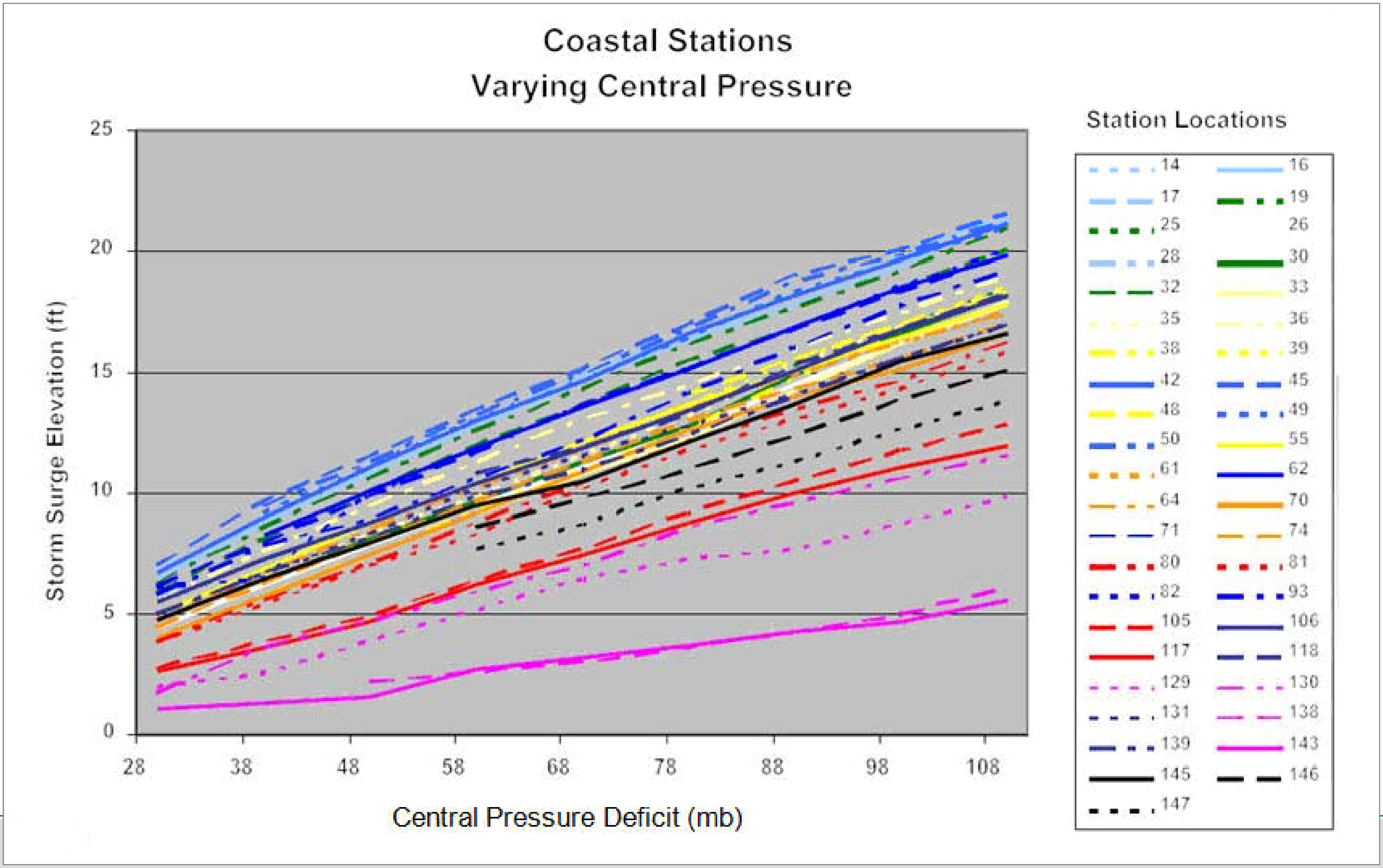
Questions?

Adjusting Flood Frequency based on change in storm frequency

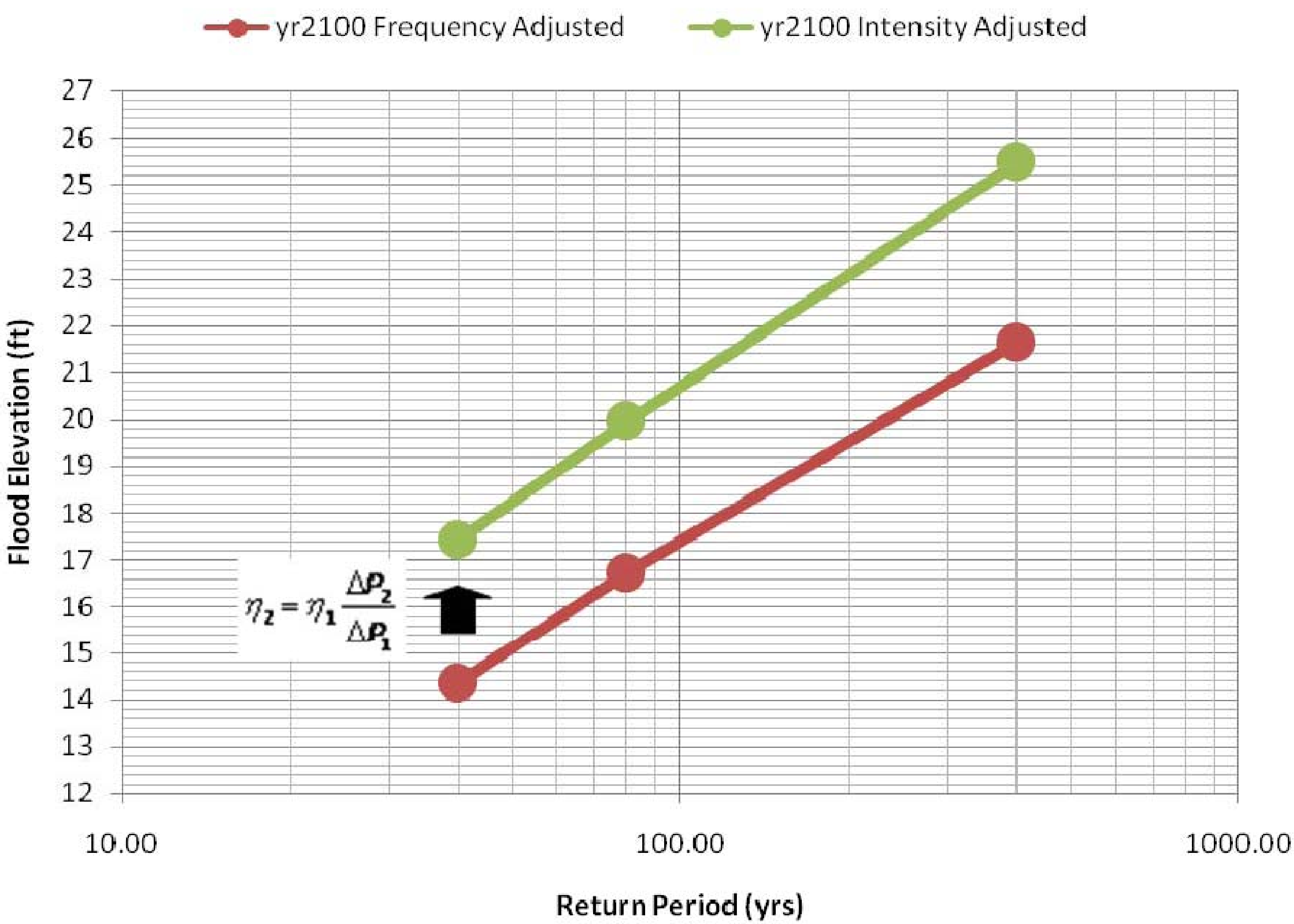


$$T_2 = \frac{\hat{\lambda}_1}{\hat{\lambda}_2} T_1$$

Coastal Storms: Varying Central Pressure



Adjusting Flood Frequency based on changes in storm intensity



Re-scaling for a Storm Frequency Change

$$\Pr\left[\eta_i\right] = \lambda.\Pr\left[x_1,\ldots,x_D\right]$$

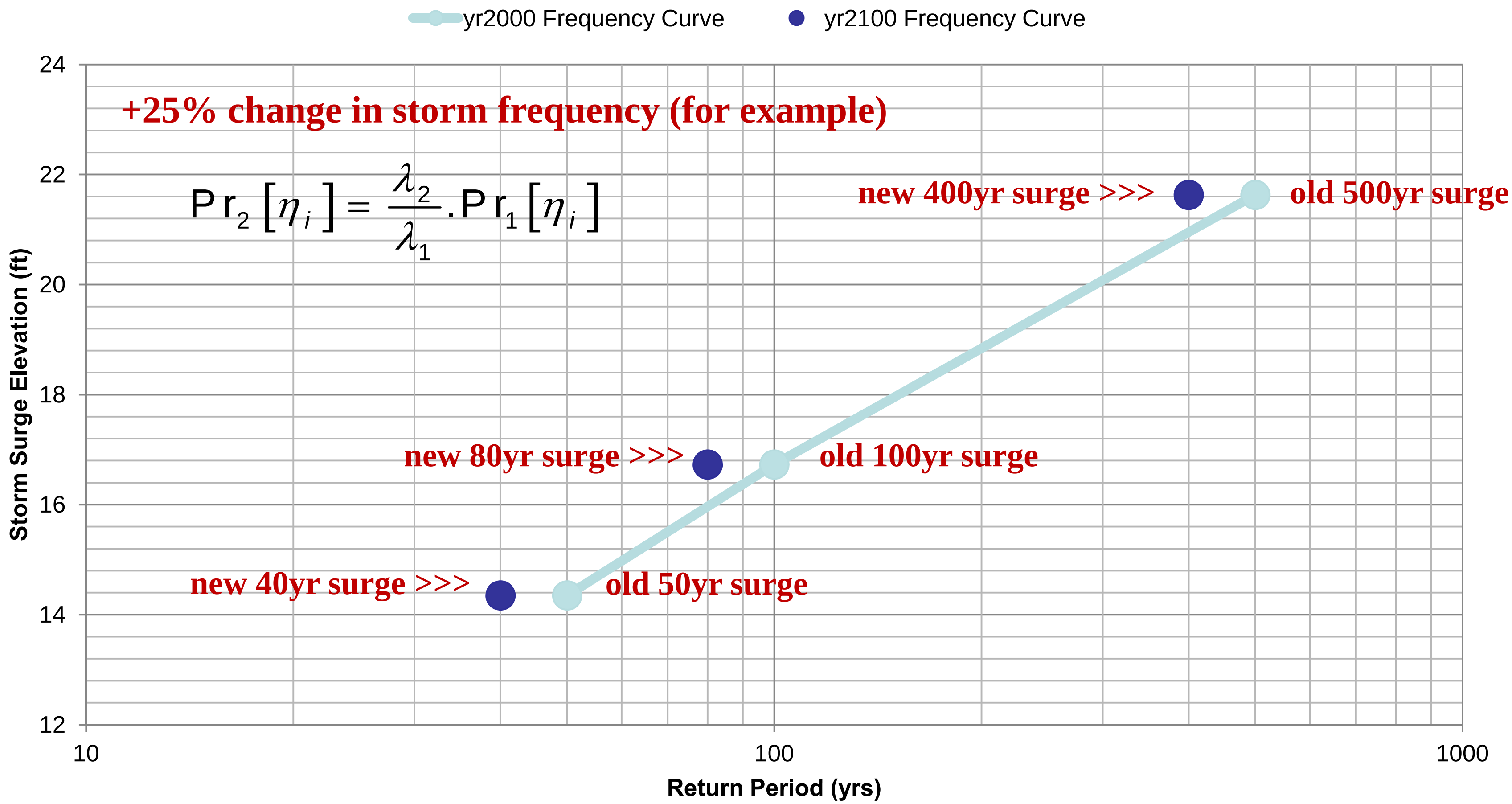
$$\Pr_2\left[\eta_i\right] = \frac{\lambda_2}{\lambda_1}.\Pr_1\left[\eta_i\right]$$

exceedance probability in new climate

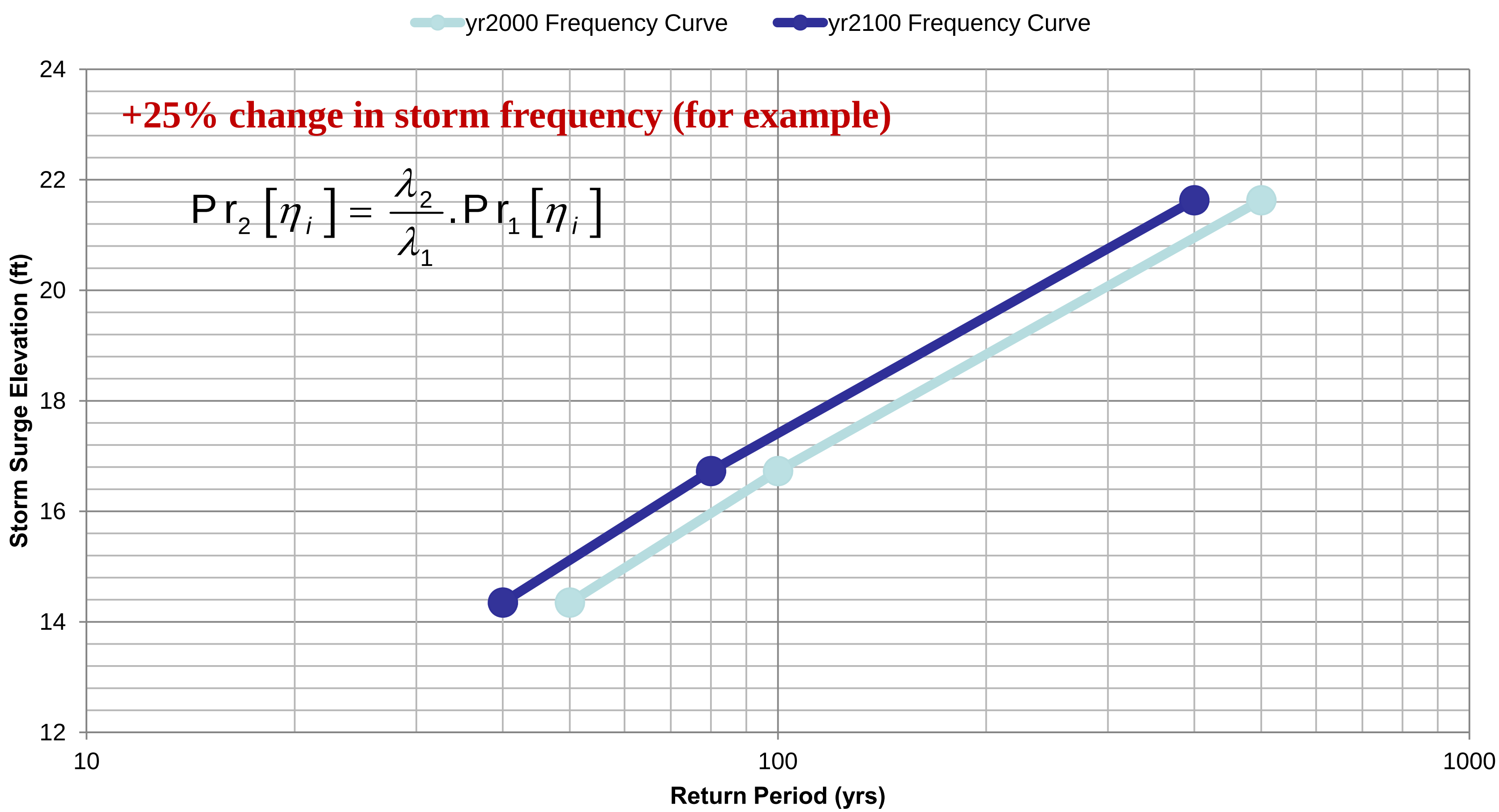
relative change in storm frequency

exceedance probability in current climate

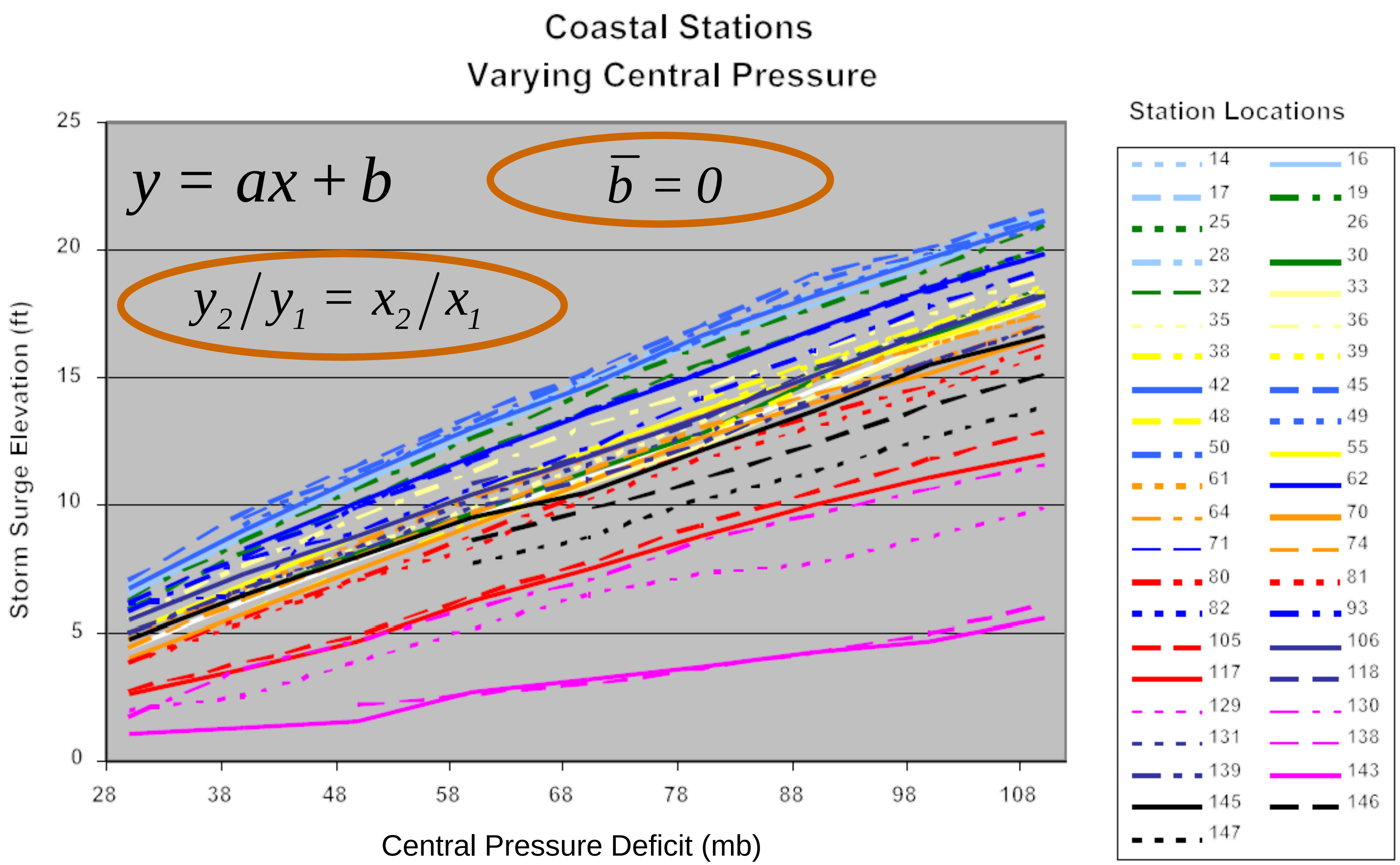
Re-scaling for a Storm Frequency Change



Re-scaling for a Storm Frequency Change



Storm Intensity – Hurricanes
(Adapted from the HMTAP Mississippi Study)



Re-scaling for a Storm Intensity Change

$$\Pr\left[\eta_i\right] = \lambda.\Pr\left[\Delta P \mid \ldots\right]$$

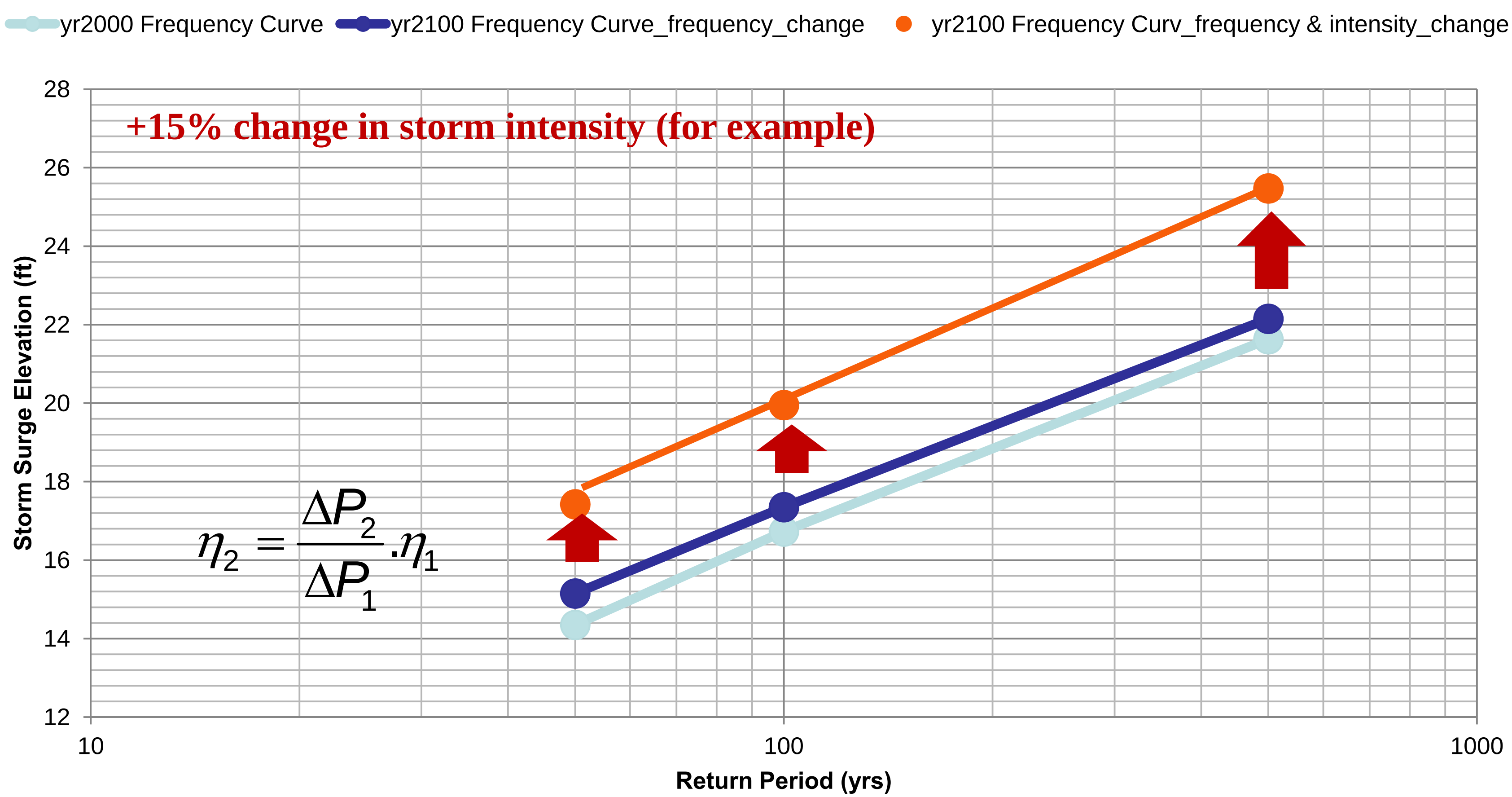
$$\eta_2 = \left(\frac{\Delta P_2}{\Delta P_1}\right).\eta_1$$

T-yr storm surge in new climate

relative change in storm intensity

T-yr storm surge in current climate

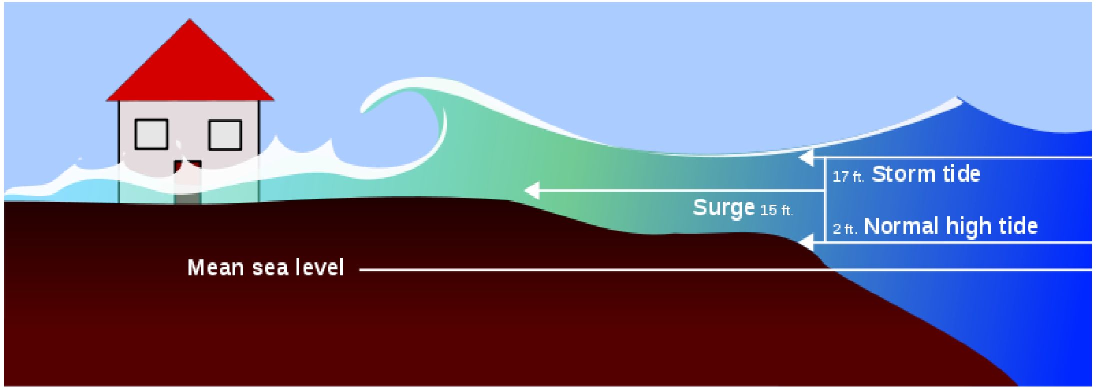
Re-scaling for a Storm Intensity Change

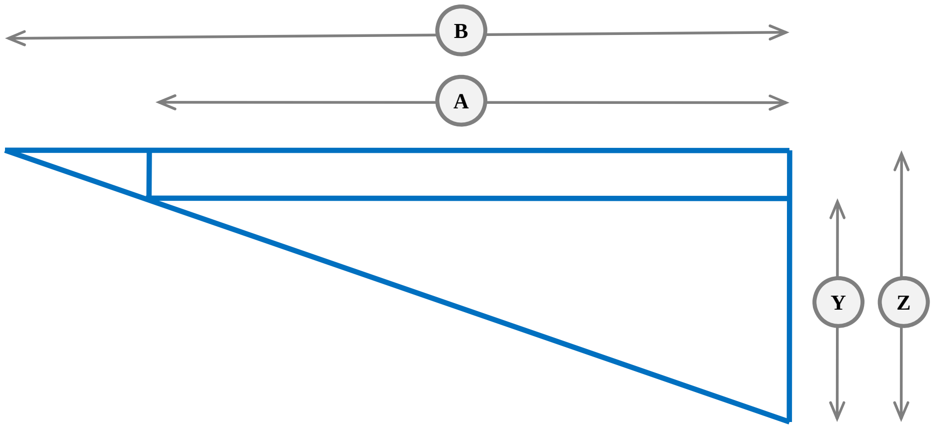


Inland Penetration of Flooding

Adopt simple idealization of a coastal transect

Inland flood penetration is approximately proportional to flood height at coast





$$B \,/\, A \approx Z \,/\, Y$$