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Using A Risk Management Approach to Guide the Response to Climate Change: A Review of Key Concepts and New Applications

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Overview

- Motivation for risk management approach
- Some basic concepts
- A simple (stylized) example
- Several real-world (and messier) examples
- Some thoughts on reaching the “full potential” of the approach

Acknowledgements

- Current collaborators/PIs:
 - Gary Yohe (Wesleyan)
 - Ken Strzepek (UC-Boulder and MIT)
- Others who have shared “in progress” climate effects work to help us illustrate the risk management approach:
 - Paul Kirshen (Tufts/Batelle)
 - Rachel Warren (Tyndall Center/Univ. of East Anglia)

Major Lessons from the IPCC Fourth Assessment Report (2007)

- The planet is committed to more warming even if emissions of greenhouse gases were halted today.
- As a result, the response to climate change is not just about reducing greenhouse gases - preparing to adapt is also important.
- “Responding to climate change involves an *iterative risk management process* that includes *both adaptation and mitigation* and takes into account climate change *damages, co-benefits*, sustainability, equity, and attitudes to risk.” [IPCC AR4, Synthesis Report, Summary for Policymakers, p22, emphasis added]

Thesis of all this work...

- **Benefit-cost analyses** to support climate decision-making are useful and necessary, but the benefits side is necessarily **focused on a subset of climate effects** that we know well.
- **Risk profiles** are an important and useful supplement to benefit-cost analyses, both to **address “missing categories” of effects** and to **facilitate risk management** in the form of adaptive actions.

Coverage of Existing Economic Analysis of the Impacts of Climate Change Related Risks

		Uncertainty in Valuation →		
		Market	Non Market	(Social Contingent)
Uncertainty in Predicting Climate Change ↓	Projection (e.g., sea level Rise)	I Coastal protection Loss of dryland Energy (heating/cooling)	IV Heat stress Loss of wetland	VII Regional costs Investment
	Bounded Risks (e.g. droughts, floods, storms)	II Agriculture Water Variability (drought, flood, storms)	V Ecosystem change Biodiversity Loss of life Secondary social effects	VIII Comparative advantage & market structures
	System change & surprises (e.g. major events)	III Above, plus Significant loss of land and resources Non-marginal effects	VI Higher order Social effects Regional collapse	IX Regional collapse

Source: Yohe and Tirpak (2008).

What Is a “Risk Management” Approach?

- Important to understand the concept that risk is defined as probability *times* consequence.
- When we know a lot about both probability *and* consequence, “expected value” of risky outcomes can be used to communicate information to decision-makers - this is approach used in most benefit-cost analyses.
- Risk management approaches are useful when we need to look at probability, or consequence, or both, in greater detail - especially when consequences are non-linear with respect to exposure.

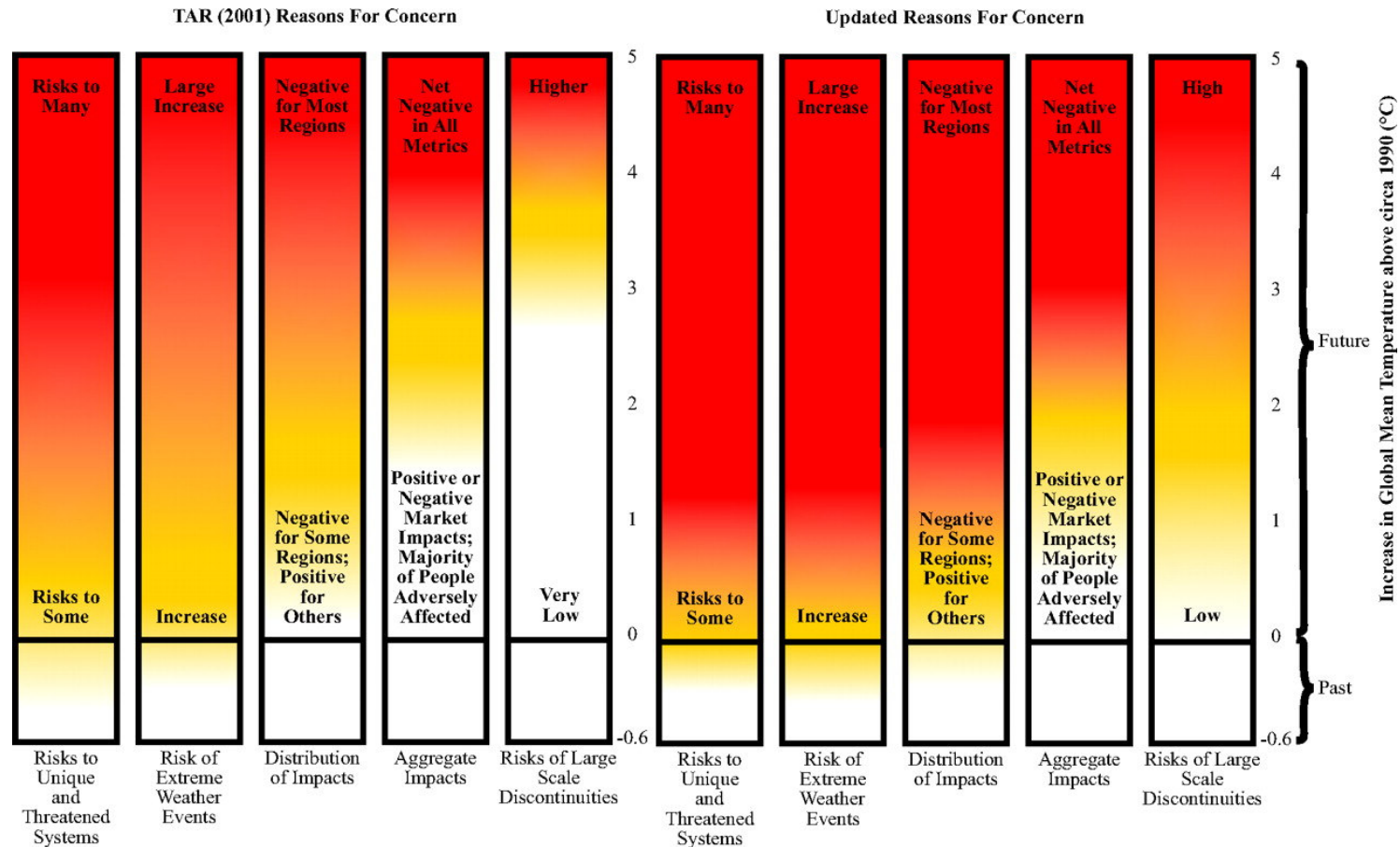
What Is a “Risk Management” Approach?

- Risk management approaches are particularly helpful when:
 - There is substantial uncertainty (temporal, spatial, or otherwise) about the probability of an event
 - There is incomplete information about the consequences of an event (unknown or not yet characterized in terms we understand or can communicate well)
 - Actors are risk-averse - so expected value isn't adequate to make a decision about how to respond

Risk Management and Climate Change

- Uncertainties in estimating consequences of climate change are large.
- For some categories of effects, consequence is large but probability is small - but we can't yet estimate probability well
- IPCC Fourth Assessment found risk-based characterizations to be useful in communicating:
 - Risks to unique and threatened systems
 - Risks of extreme weather events
 - Risks of large-scale catastrophes

Communicating Risk via the “Burning Embers”



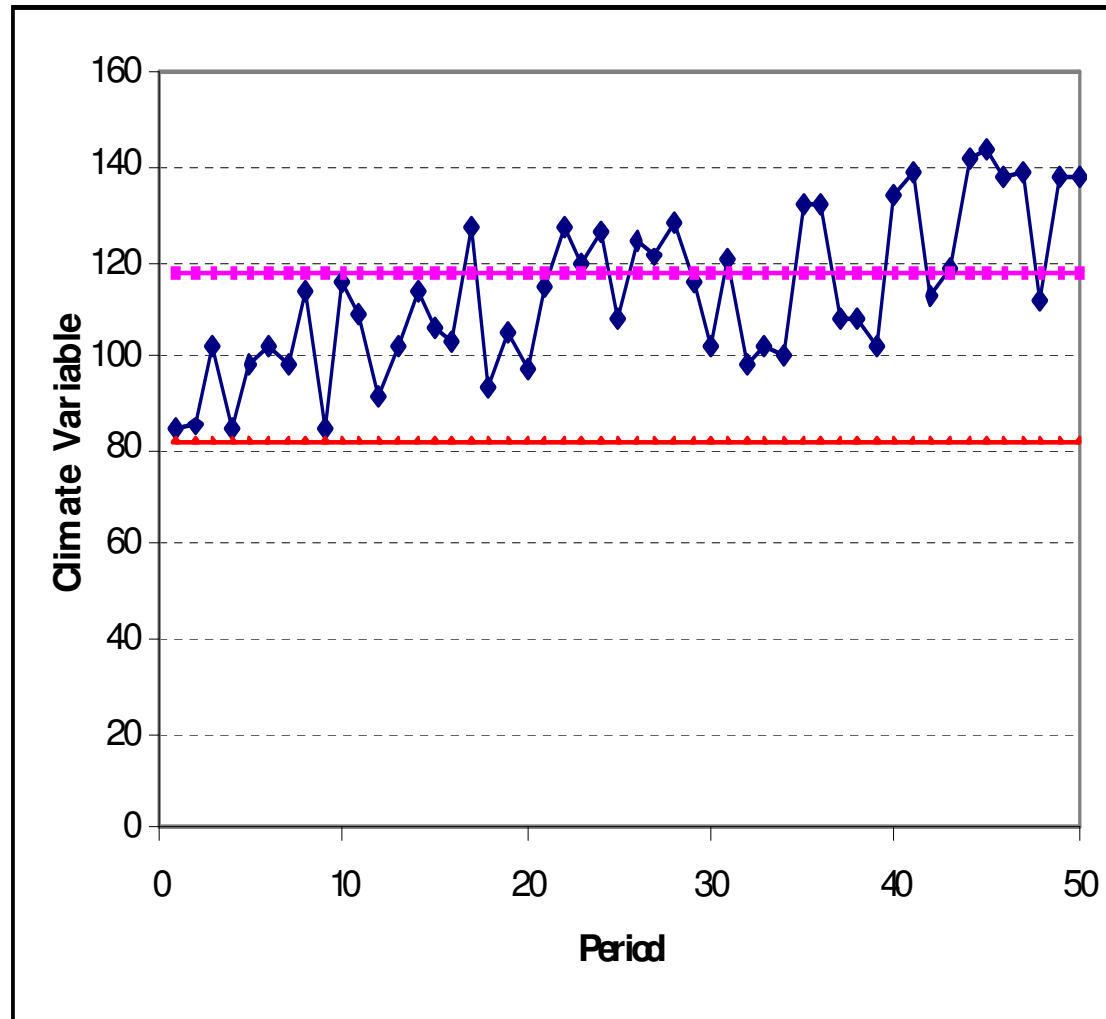
Smith J. B. et.al. PNAS 2009;106:4133-4137

Simple Example of Risk-based Approach

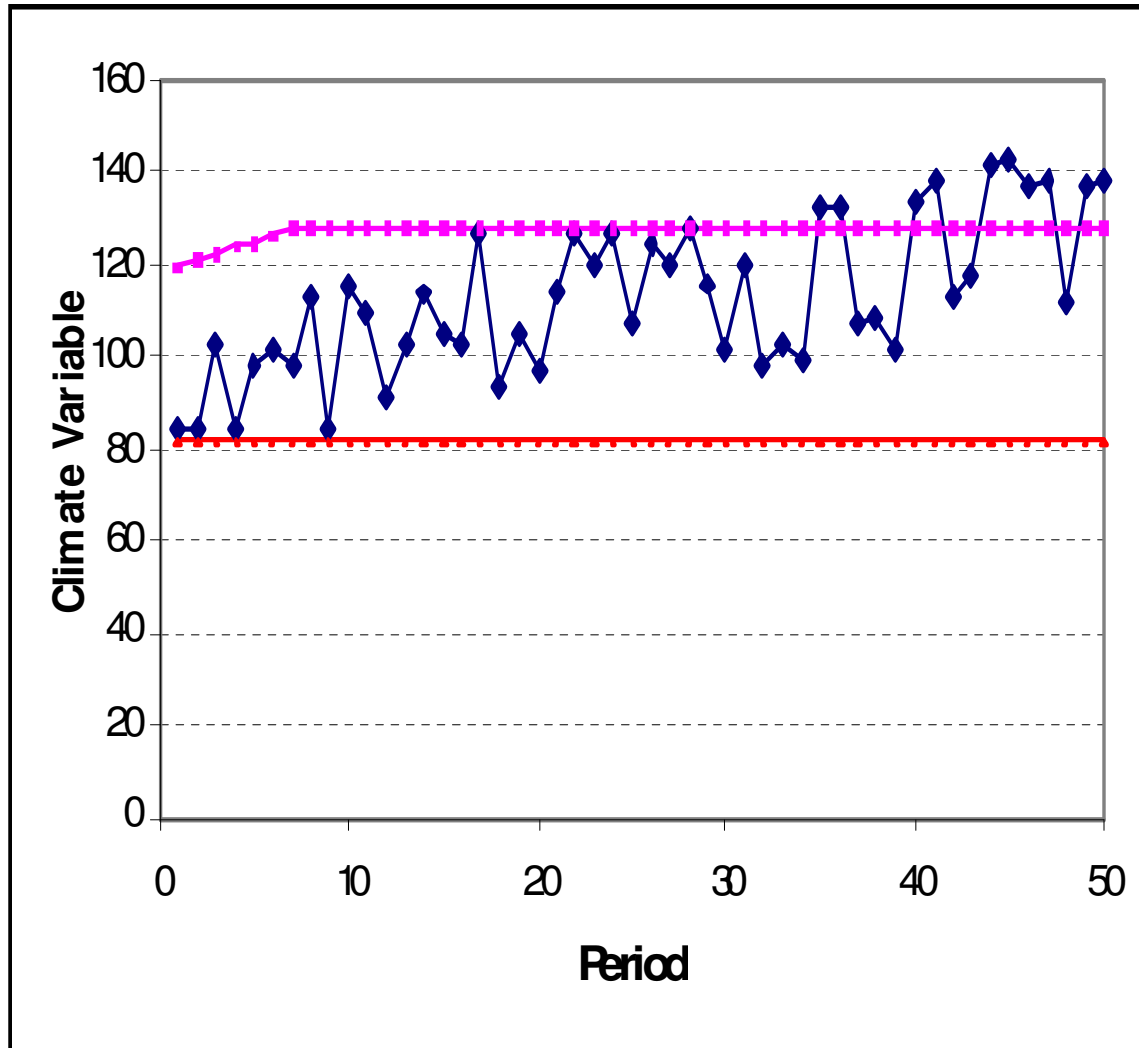
- Estimate chances of crossing a “high consequence” threshold under alternative scenarios.
- Examples of relevant climate-related thresholds include:
 - Temperature threshold
 - Storm event of a specified intensity
 - Species extinction
 - Drought
- Key outcome: how does climate change alter the risk of a clearly definable event occurring in any given year?

An Artificial Illustration - The Baseline

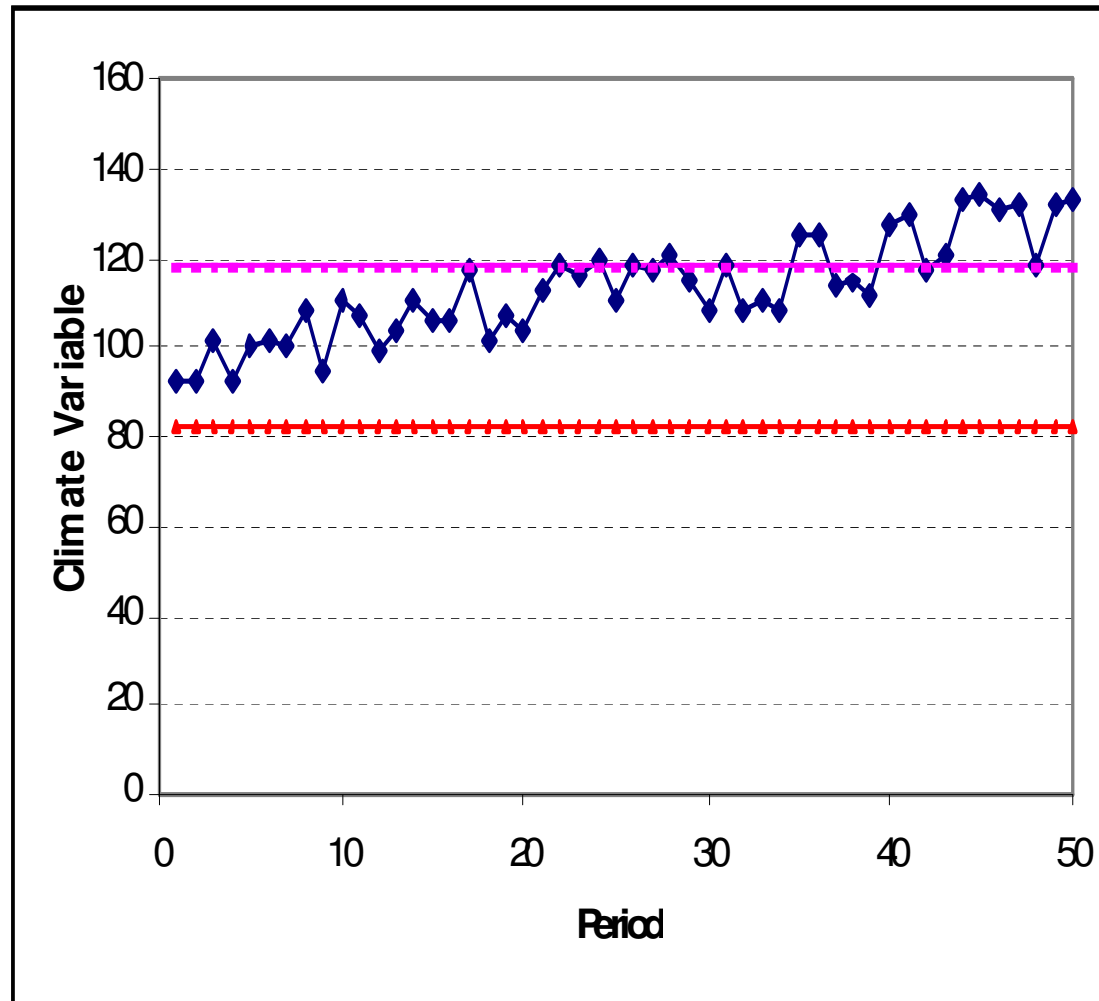
(17 Threshold Breaches)



Adding Adaptation Alone (10 Threshold Breaches)

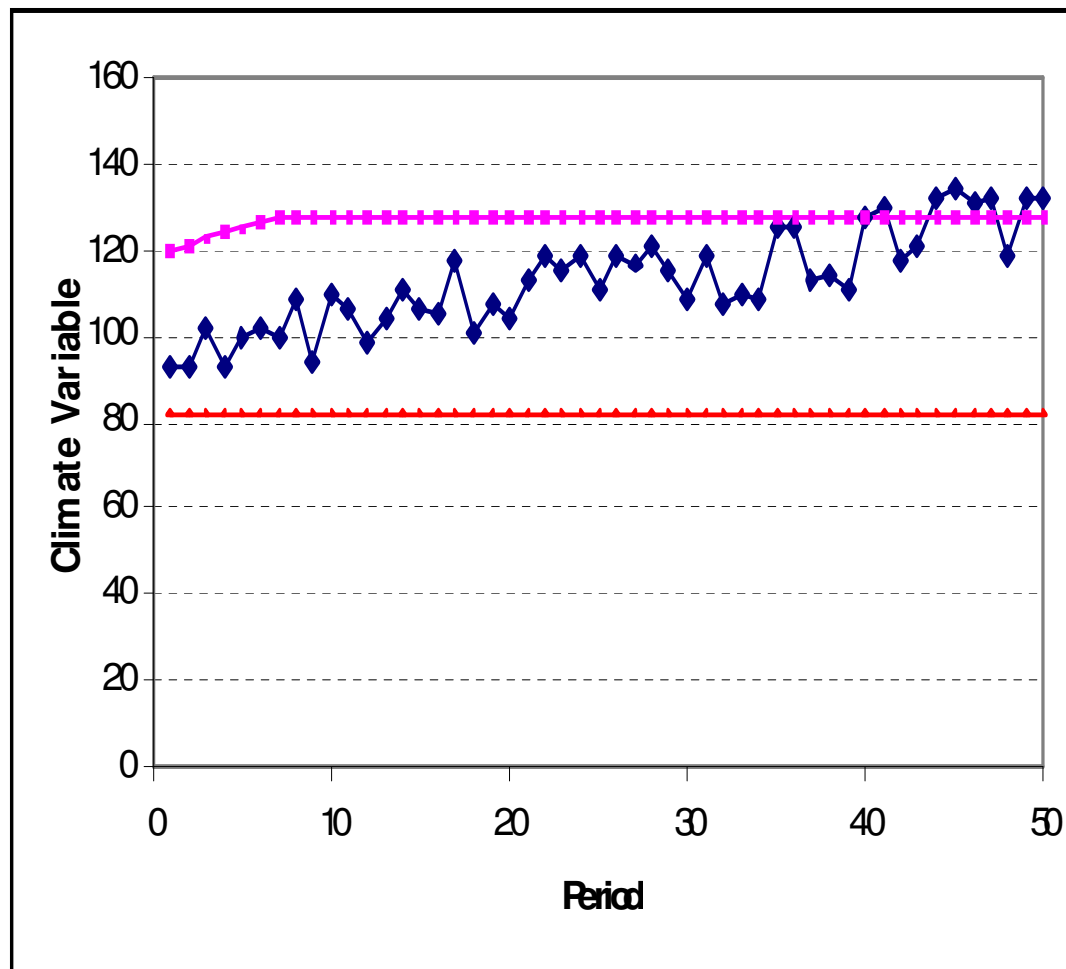


Adding Mitigation (Smoothing) Alone (12 Threshold Breaches)



Adding Mitigation with Adaptation

(7 Threshold Breaches)



A “Real World” Example

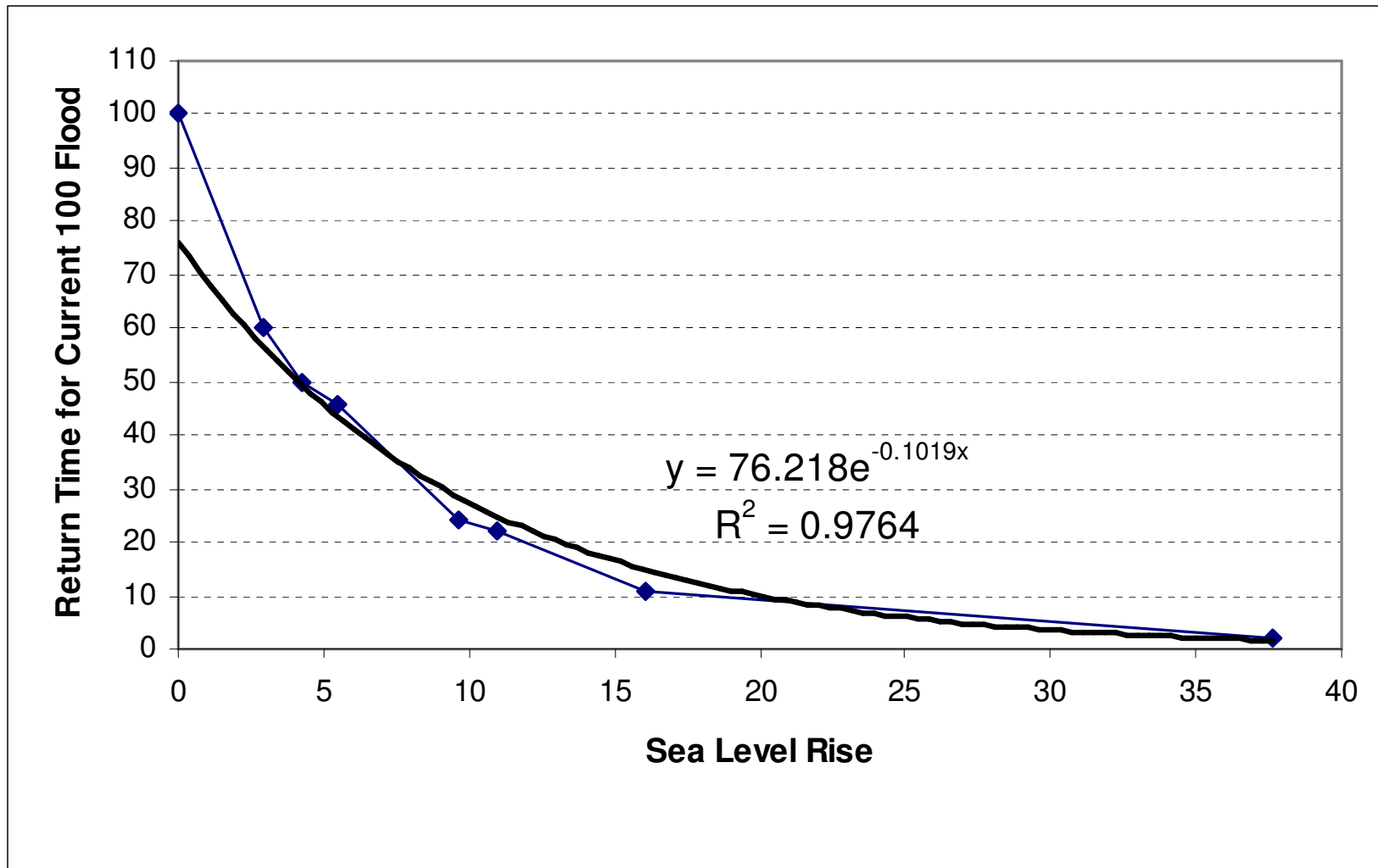
- Risk of the 100-year flood in New York City (from Kirshen et al. in press, and Yohe analysis):
 - Difficult to characterize consequences of the event definitively
 - But we can think rigorously about probability of this event
 - Key local decision is how and when to invest in adaptive measures (building sea walls, enhancing pumping capacities, changing building codes)
 - Key local input to national policy question might be how to balance mitigation with adaptation

Risk Management Example - NYC and the 100-Year Flood



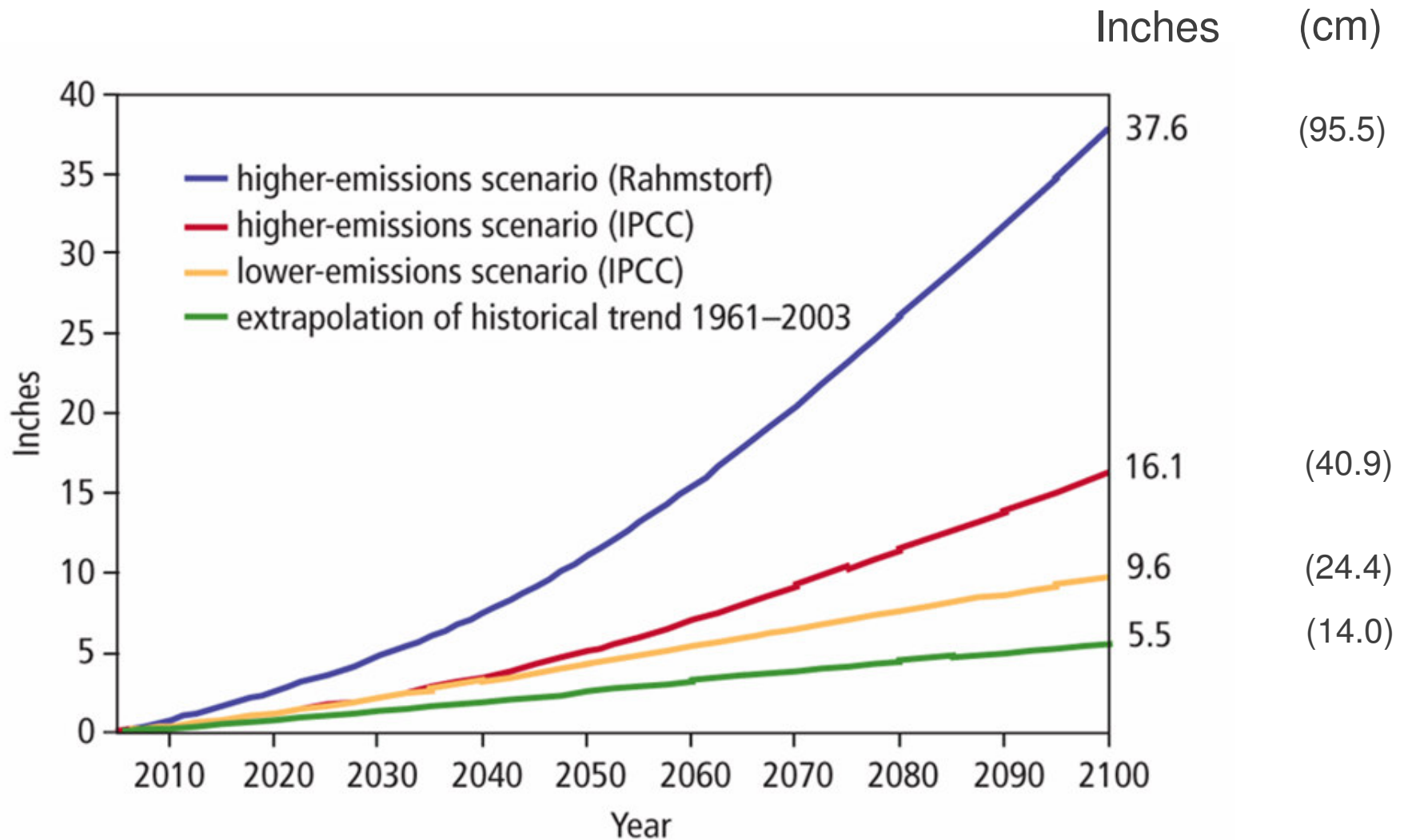
www.climatechoices.org/ne/

Frequency of 100-year flood is altered by sea-level rise



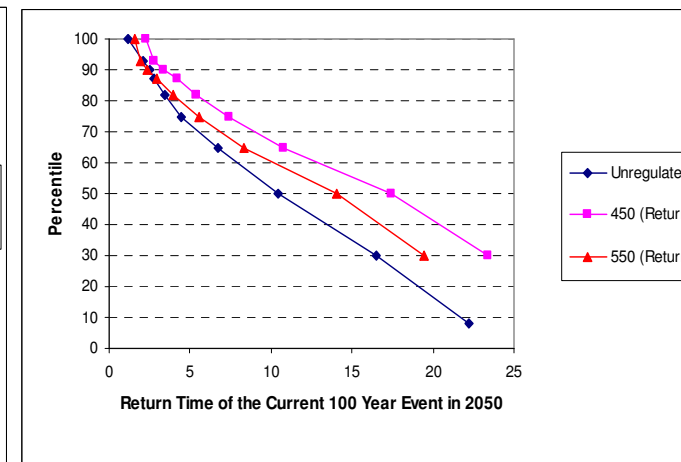
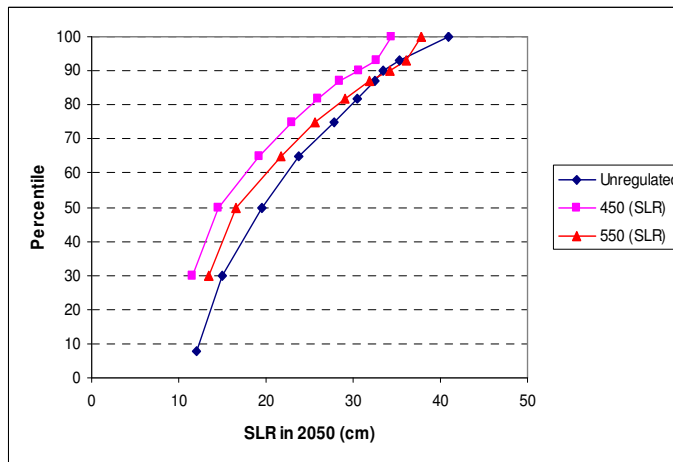
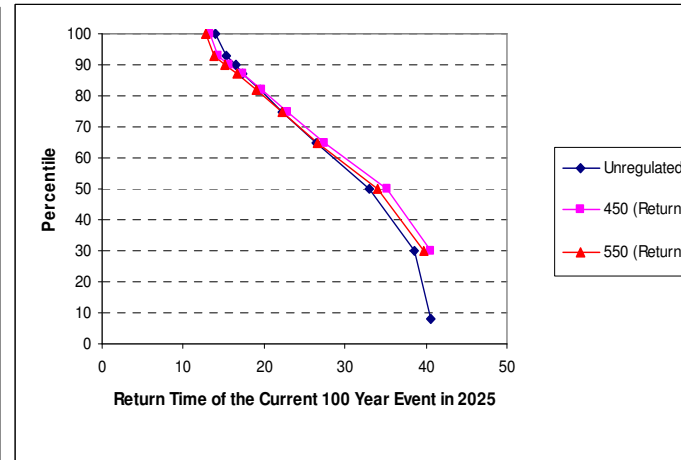
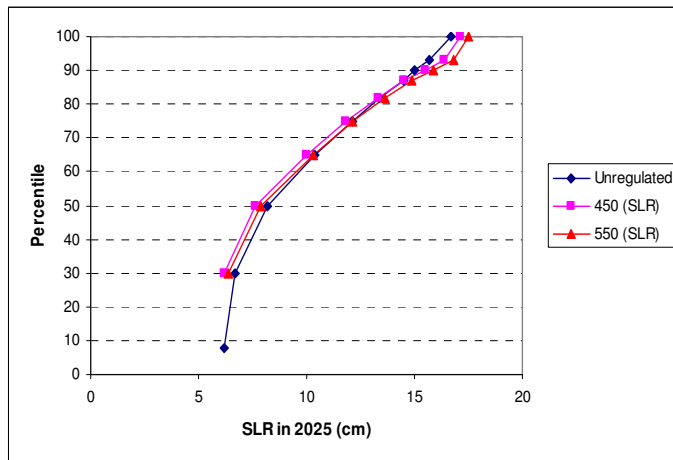
Source: NECA/UCS, 2007 (see: www.climatechoices.org/ne); SLR in inches

Combine that relationship with trajectory of sea level rise over time...



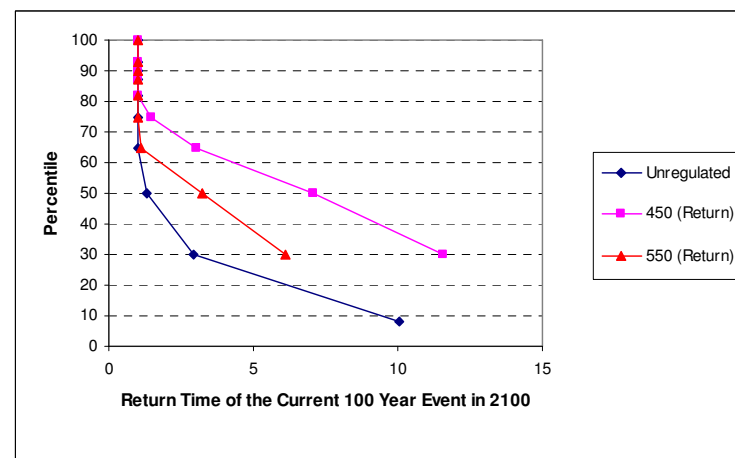
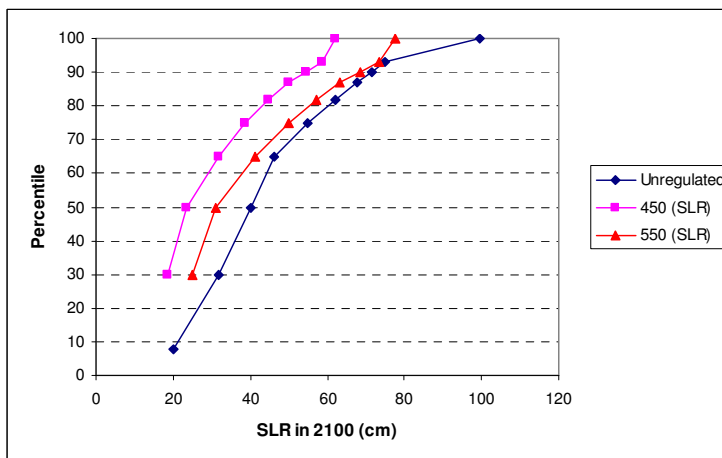
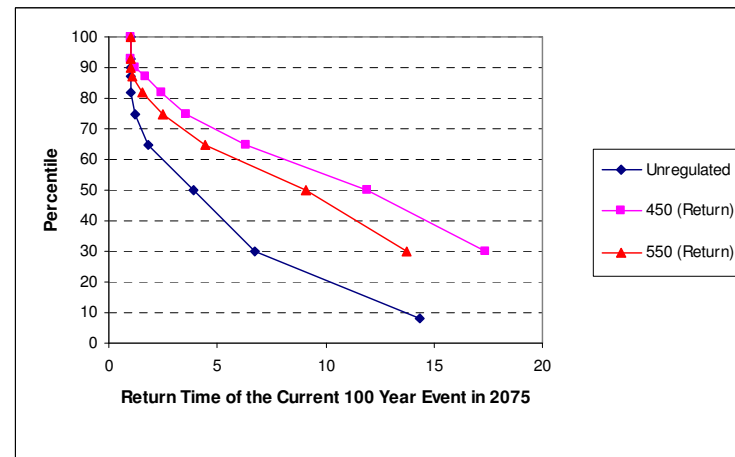
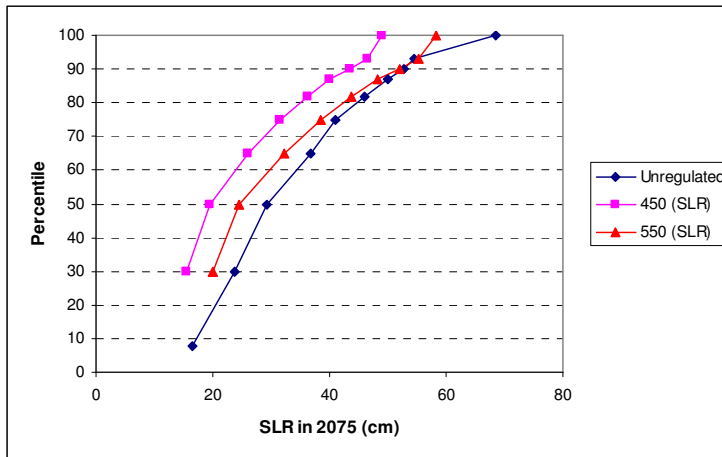
Source: NECIA/UCS, 2007 (see: www.climatechoices.org/ne)

And add subjective probability distribution of alternative SLR outcomes...

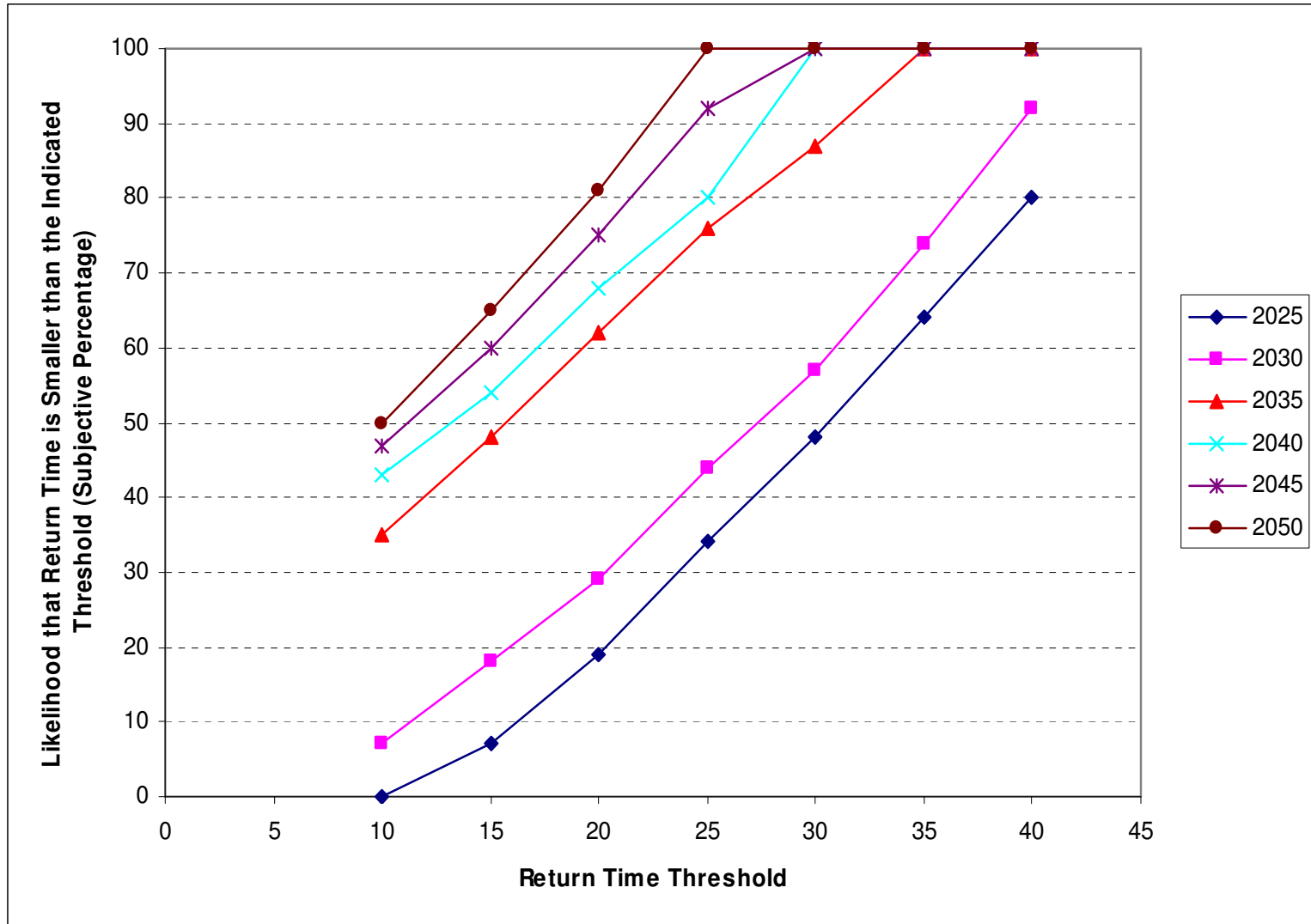


...result is Cumulative Distributions of Sea Level Rise (left) and Return Times (right) of the 100-year flood in NYC (in 2025 and 2050)

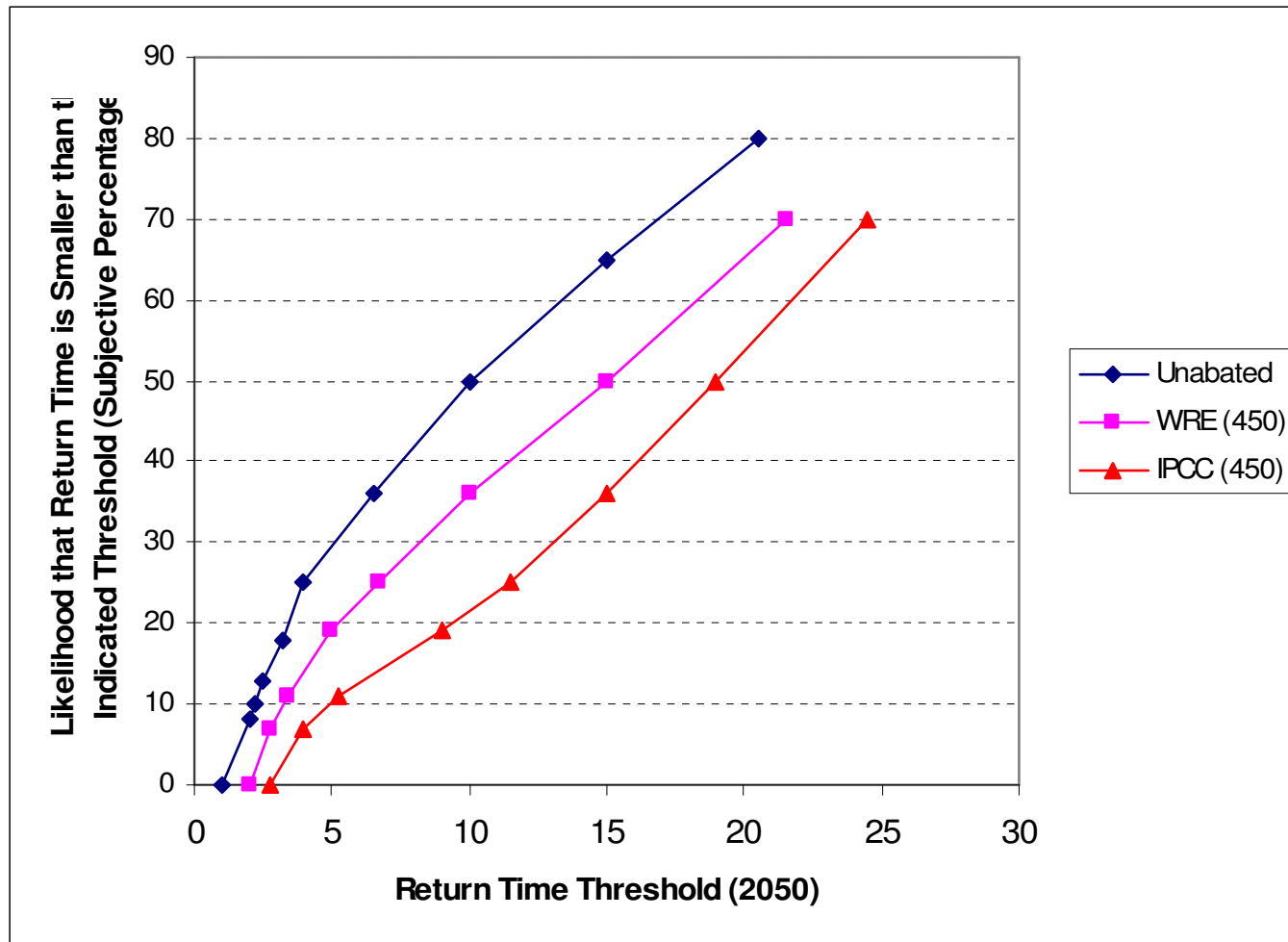
More Cumulative Distributions of Sea Level Rise and Return Times of the 100 Flood in NYC - 2075 and 2100



Re-cast for local decision-makers, for unabated emissions trajectories



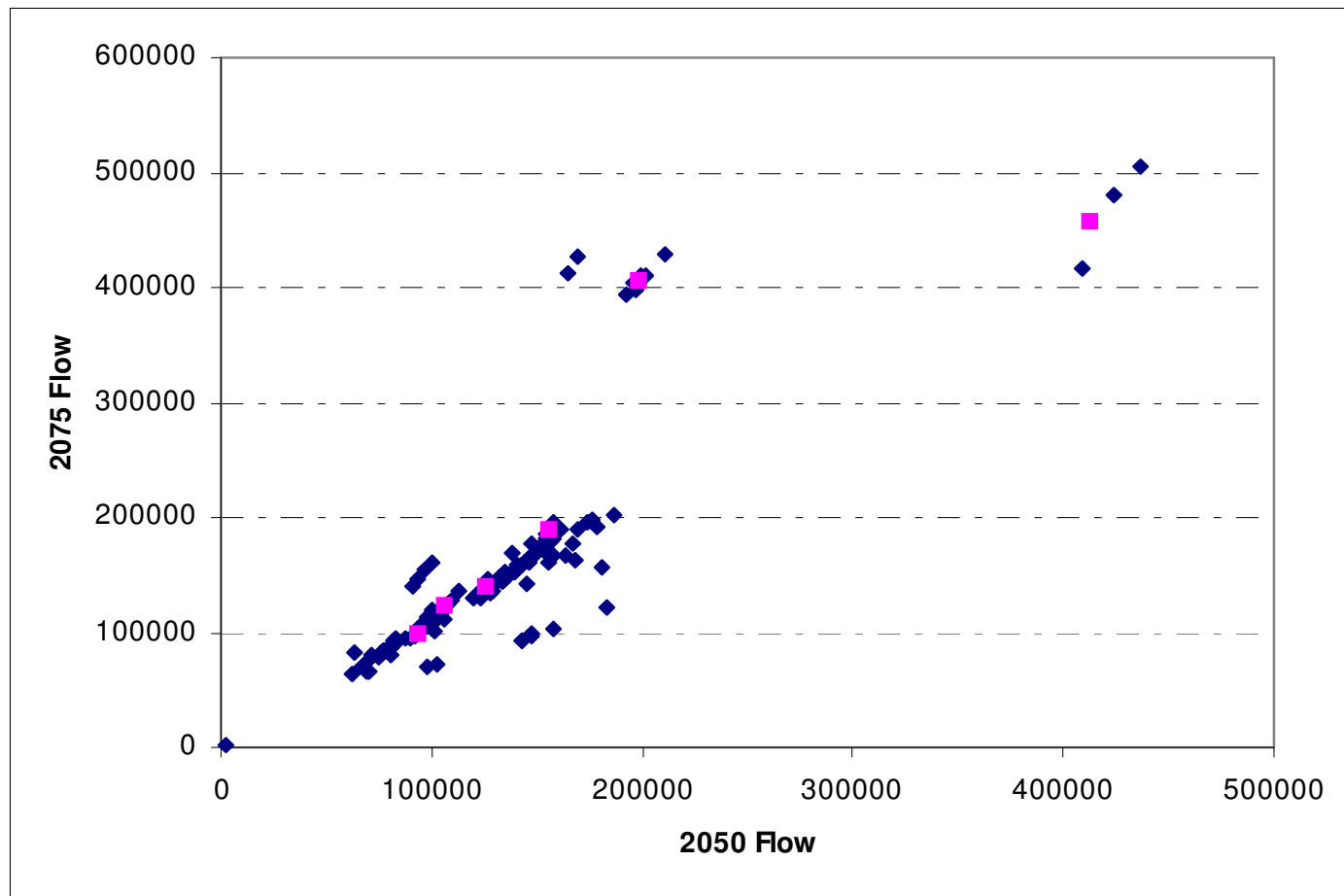
Alternatively, Look at the Effect of Mitigation (in 2050)



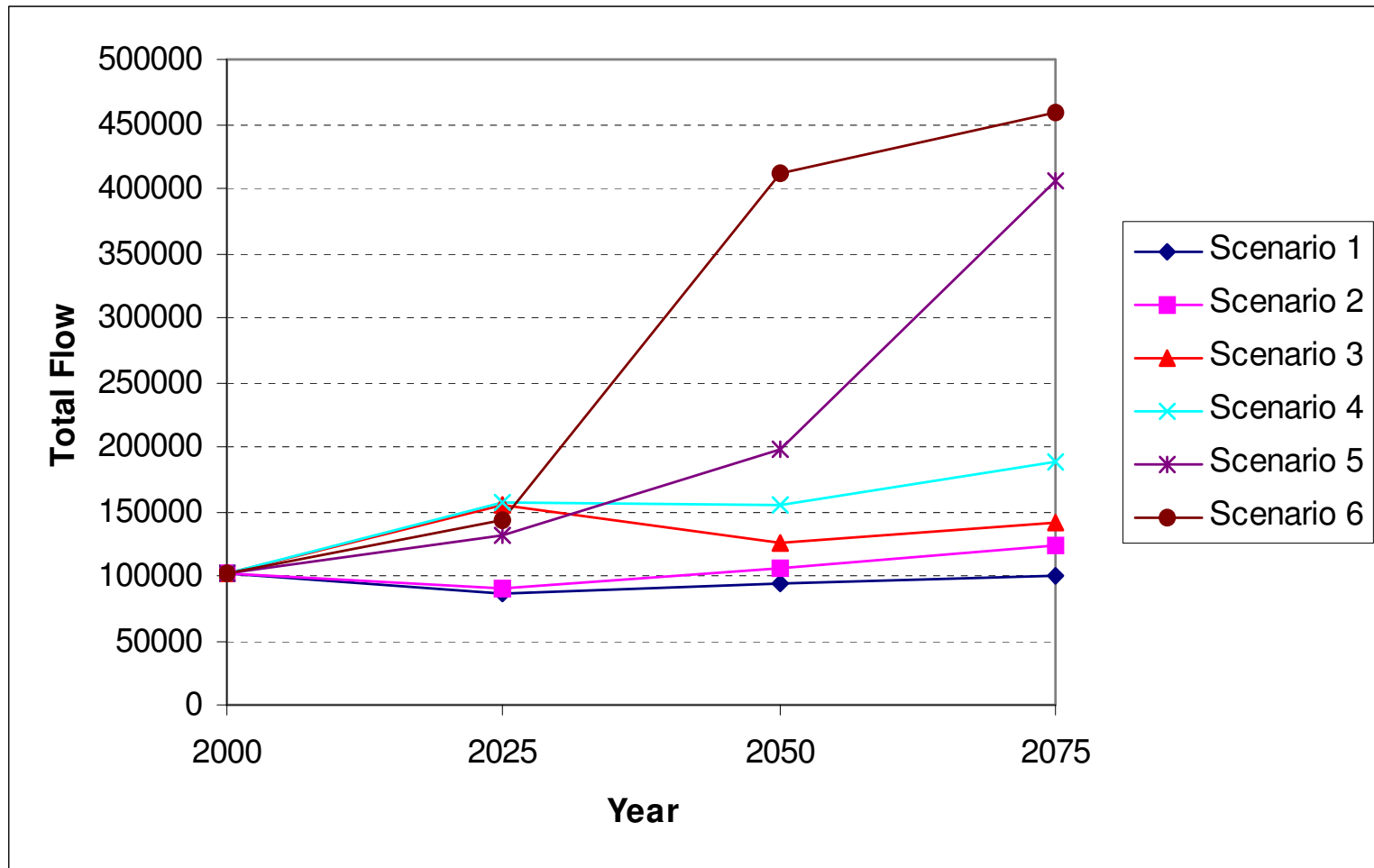
Another Example: Flooding along the Ganges and Brahmaputra

- Question: Effect of adaptation and mitigation on climate-induced changes in the likelihood of modest, moderate, and severe flooding.
- Calibrate a hydrologic model of river flow in the basin to output from a climate change model output (monthly rainfall in Nepal).
- Estimate a relationship between flow and the likelihood of various types of flooding (indexed on return time).
- Run a climate model (COSMIC) to produce representatives of “not-implausible” futures without mitigation or adaptation.
- Repeat with adaptation and mitigation along alternative GHG emissions scenarios.

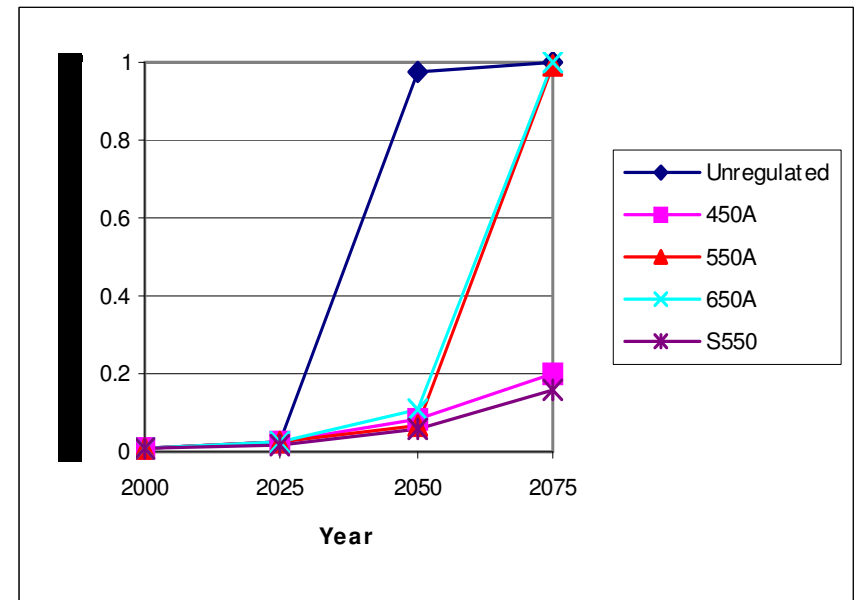
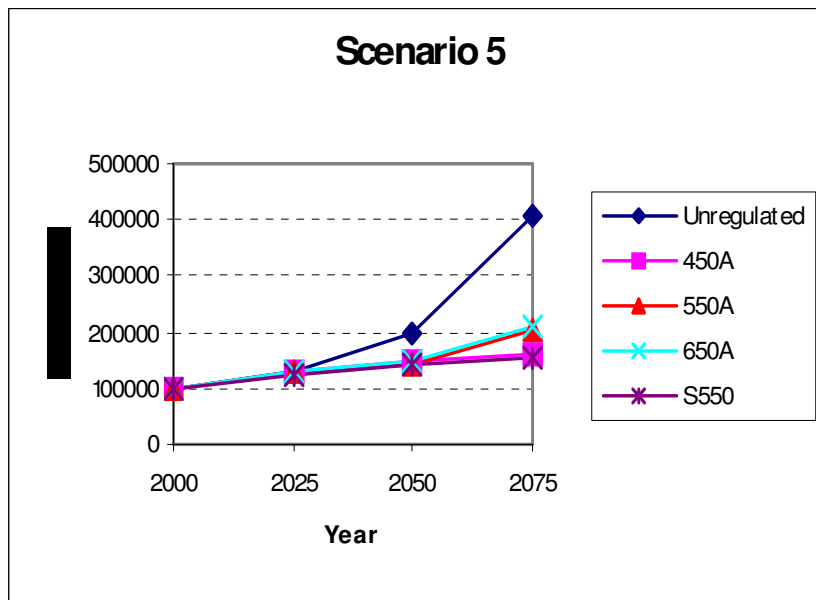
Flow Rate “Futures” from the COSMIC Calibration - Sources of the Representative Futures



Time Trajectories for Six Climate Model Alternatives/Scenarios



Illustrative Results from Scenario 5



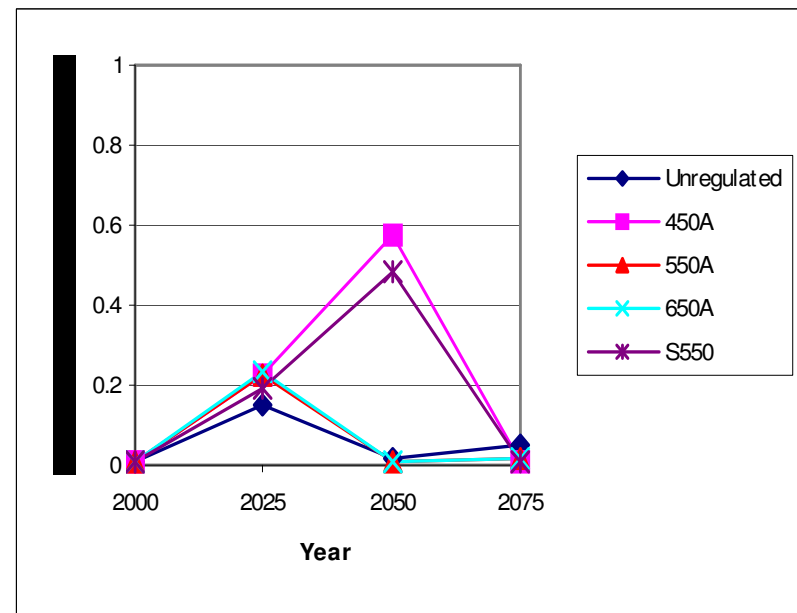
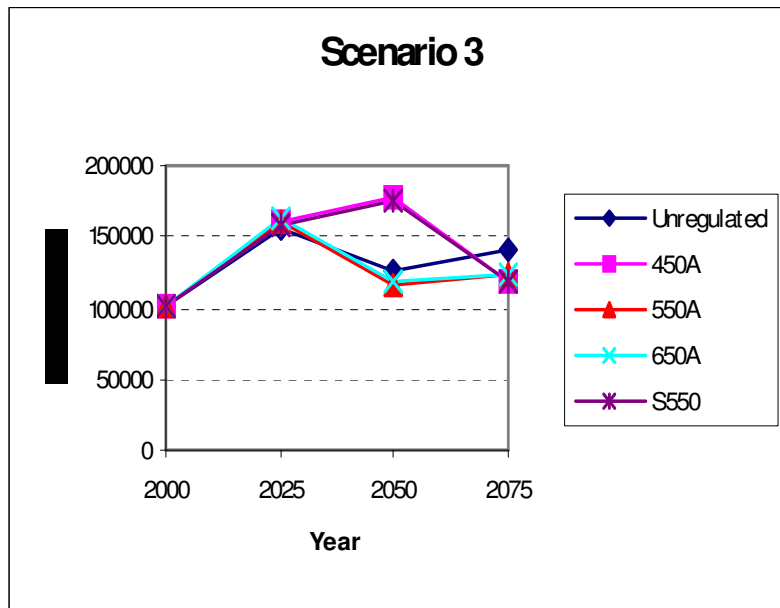
Each “scenario” (a single climate model and sensitivity) yields results for different emission scenarios:

1. Business as usual (unregulated)
2. Four GHG mitigation scenarios: 450A, 550A, 650A and S550

Some Observations from Scenario 5

- The likelihood of severe flooding increases over time in all cases.
- Mitigation seems to have an important effect - most of the mitigation alternatives look better than business as usual.
- The system (without adaptation) can be overwhelmed by climate change even with some mitigation (650A).

Results from Scenario 3



Some Observations from Scenario 3

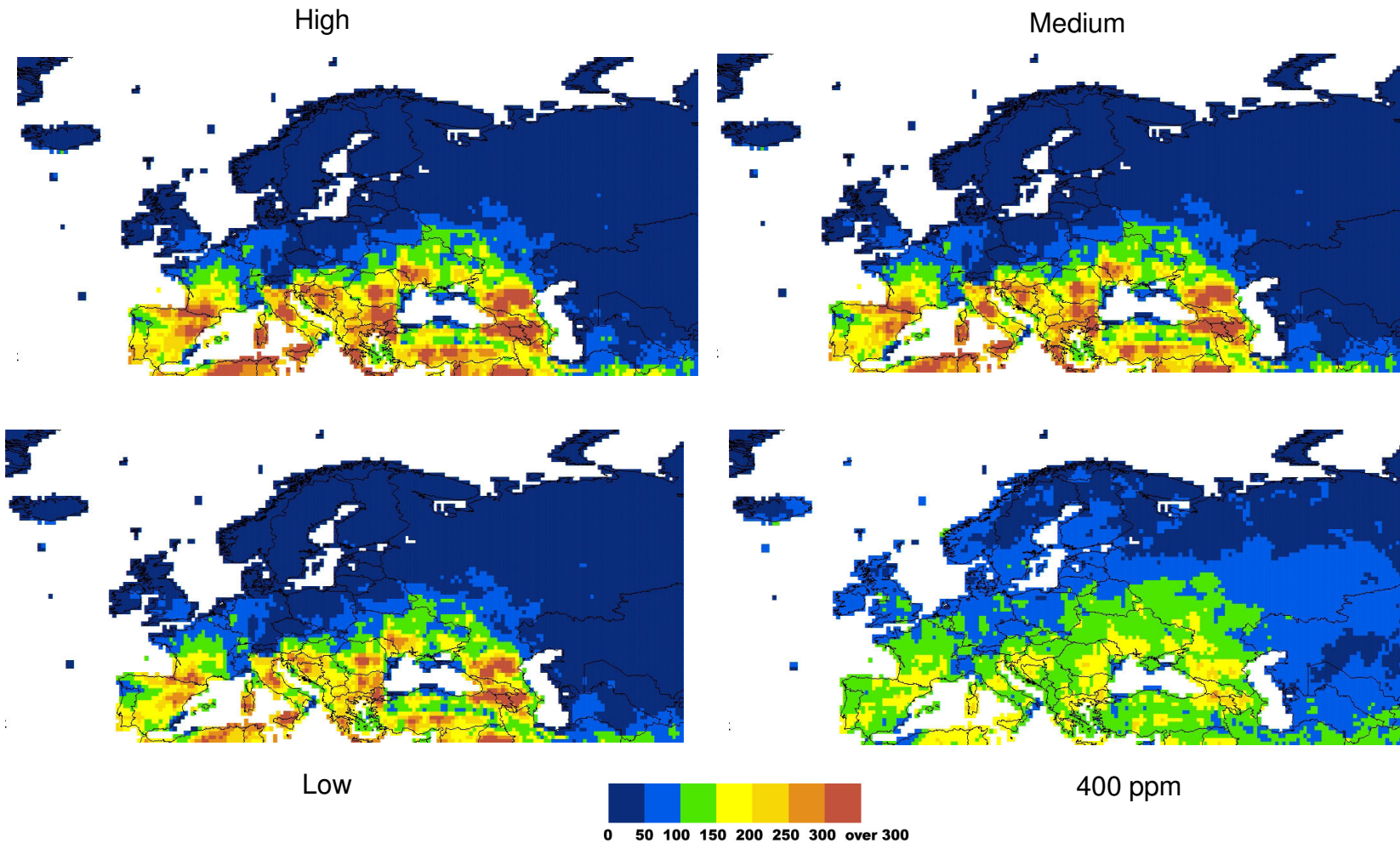
- The trajectory showing likelihood of risks does not steadily increase over time - in later years, the risk decreases.
- Mitigation might actually make things worse (compare unregulated to S550 and 450A), at least for a while.
- The system need not be overwhelmed by climate change even without any mitigation (unregulated).

Risk Management Example: Drought Risk in Europe

- Question: how does climate change alter the risk of drought in Europe? (Warren and colleagues, work in progress)
- Use a measure of drought (Standardized Precipitation Index, SPI5 and SPI12), calibrated to historical period.
- Determine a threshold value for SPI5 and SPI12.
- Assess how mitigation might affect risk of drought with that threshold value.

Note: SPI is number of location-specific standard deviations from location-specific long-term mean.

Risk Management Example: Some Very Preliminary Results on Drought Risk in Europe



0 50 100 150 200 250 300 over 300

Number of months

Source: Communication with the author;
selected HadCM3 results

Work in Progress: A similar application for drought risk in the U.S.

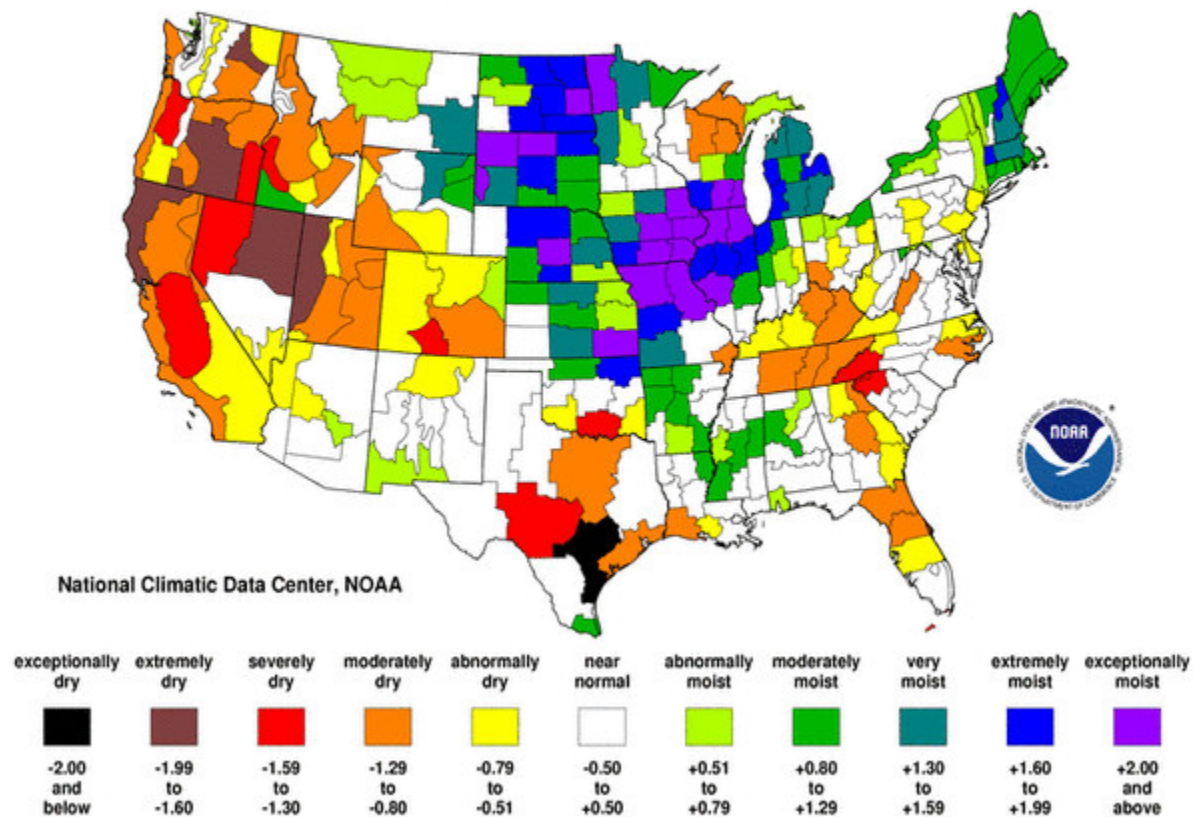
Our Question: How does climate change affect drought risks, of various definitions, in US?

1. Use results of 22 IPCC GCMs, look at three IPCC SRES scenarios (A2, A1B, B1), and three forecast eras:
 - Early 21st Century - 2016 to 2035
 - Middle 21st Century - 2036 to 2065
 - Late 21st Century - 2066 to 2095
2. Look at precipitation, runoff, and storage results; assess drought risk for various definitions: SPI, Palmer, Drought Frequency Index, etc.
3. Aggregate results to one variant US Water Resources Regions (96 regions)
4. Overlay GIS representations of water use on results

SPI12 in the US - current data

Standardized Precipitation Index Twelve Months

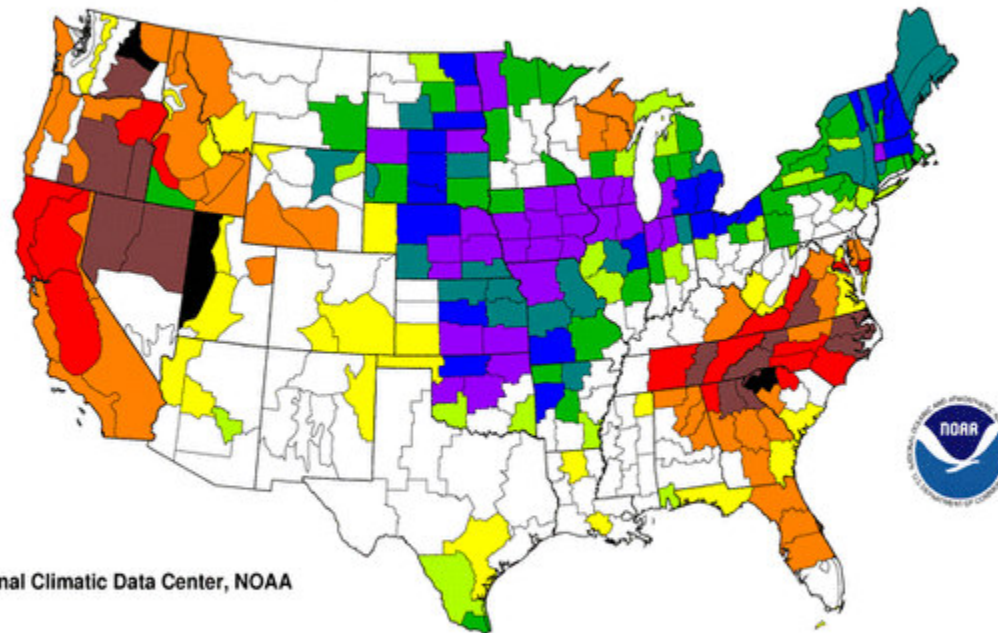
April 2008-March 2009



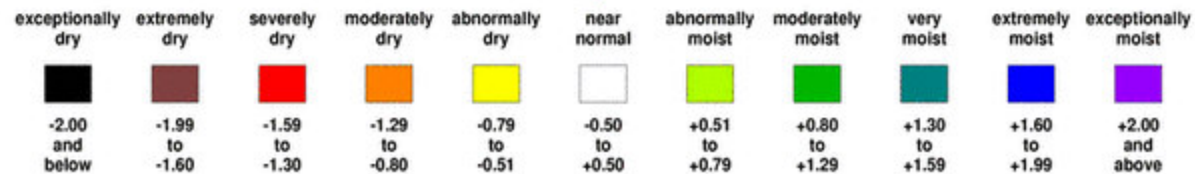
SPI24 in the US - current data

Standardized Precipitation Index 24 Months

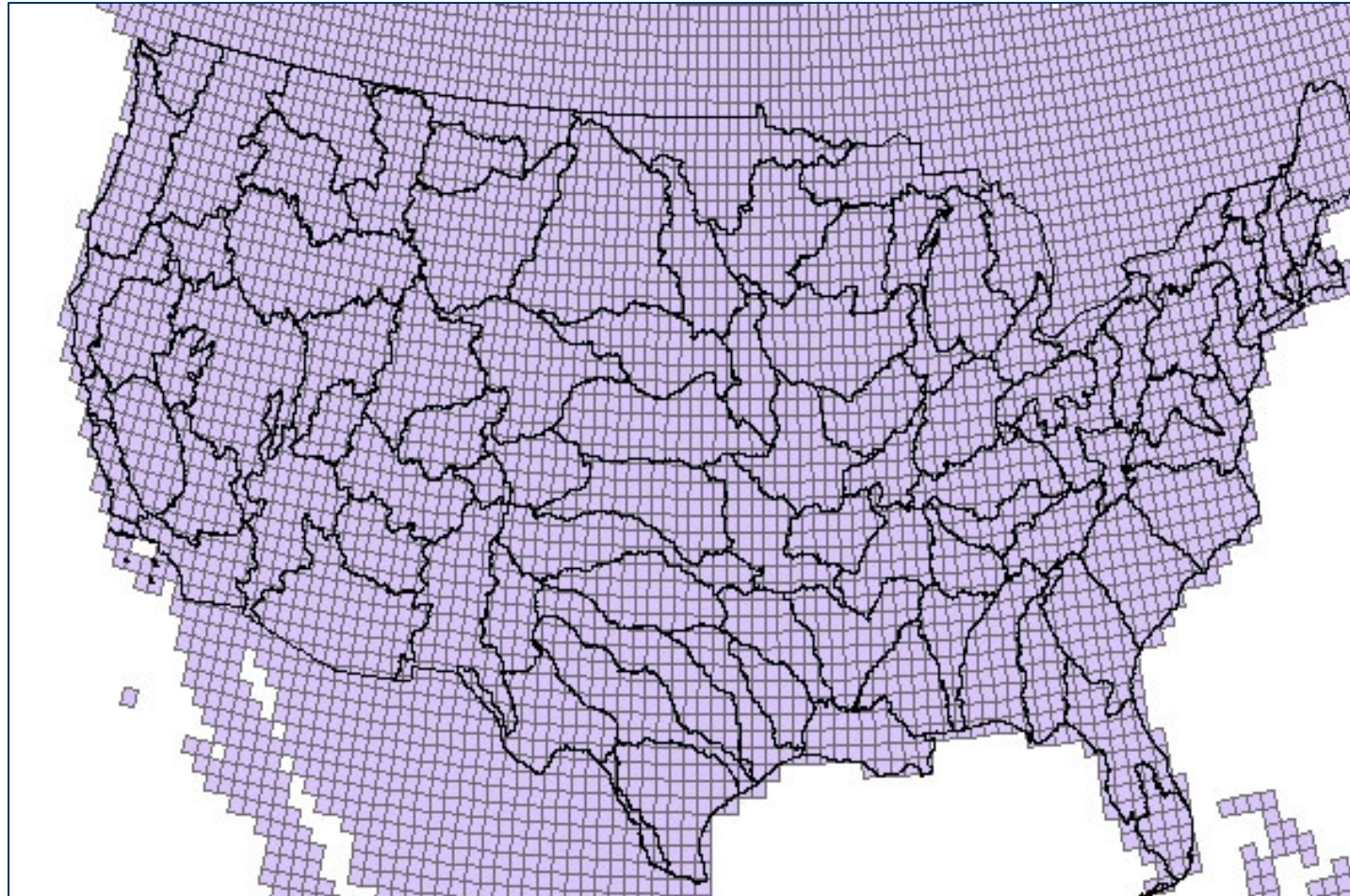
April 2007-March 2009



National Climatic Data Center, NOAA



Work in Progress: Issue of geographic resolution



Review of the three examples

1. 100-yr coastal flood risk in NYC

- SLR/surge relationship suggests near-term risks
- Can use risk profiles to elicit local-scale thresholds of concern (in terms of “tolerable return time”)
- Apply to changes in storm intensity, frequency, and track

2. Bangladesh riverine flood risk

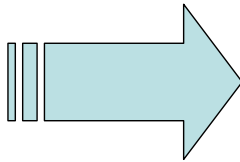
- Precip and runoff outcomes complicated, not monotonic
- This makes the choice of scenarios/models a critical step
- Insights limited by lack of knowledge of relative likelihood of scenarios

3. Drought risk

- Adding spatial dimension informative, communicates risks well
- Definition of extreme outcome (drought) is critical
- US work suggests a broad screening level approach with follow-up case studies

Risk Management Measures as a Policy Tool

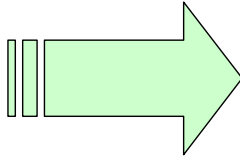
Benefit-cost framework



Economic costs and benefits

- Including marginal analysis and benefit-cost analysis recognizing adaptation
- Sensitivity to filling in the matrix
- Uncertainty on parameters and policy perspectives:
 - Conventional applications
 - Risk averaging and discounting
 - Global view for mitigation

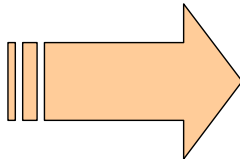
Risk framework



Risk approach to standard events (climate variability) and major events (abrupt changes)

- Risk analysis and risk portraits
- Pre-cautionary consideration of major events and tipping points, plus ecosystems, and ecological functions
- Possibility of positive risks
- Include economic analysis for risk
- Include application to adaptation decisions
- Extend to social risk

Social framework



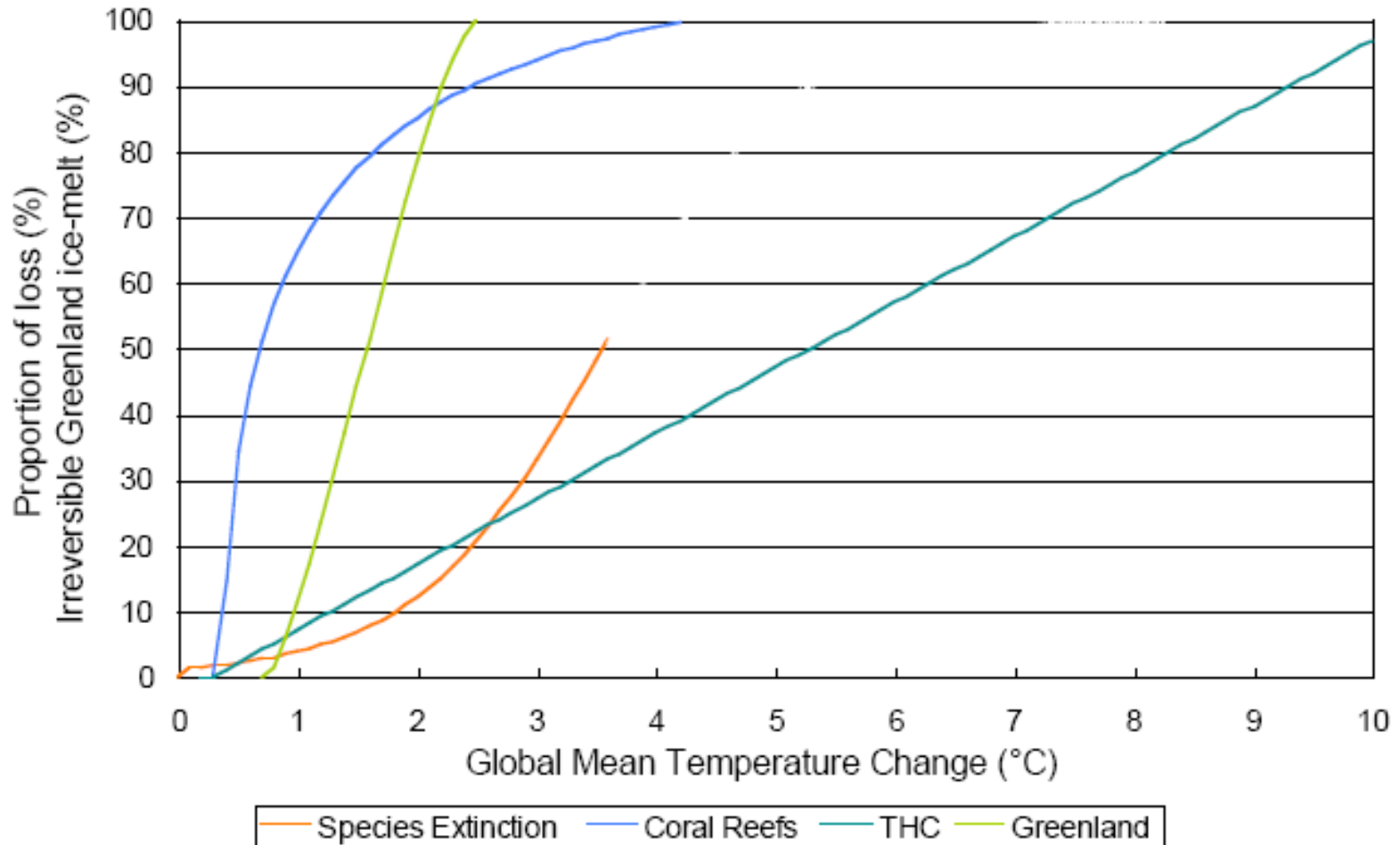
Multi-attribute frameworks accounting for multiple impacts and inequalities

- Disaggregated winners and losers
- Physical impacts (number of impacts)
- Human well-being and social indicators
- Inequality and distributional effects
- Health, settlement and welfare
- Development issues
- Social sciences

Risk Profiles complement Benefit-Cost calculations because they ...

- can show the need for adaptation over time
- can show the need for contemplating tolerable risk levels
- can show that some significant vulnerabilities can appear in the middle of the distributions
- can show sensitivities of risk to mitigation and thereby reflect the value of mitigation and the sensitivity of this value to timing
- can be expressed as unitless losses, so they can be compared across multiple metrics and therefore across multiple manifestations of climate change.

Example Presentation of Unitless Damages



Source: Jones and Yohe (2008).

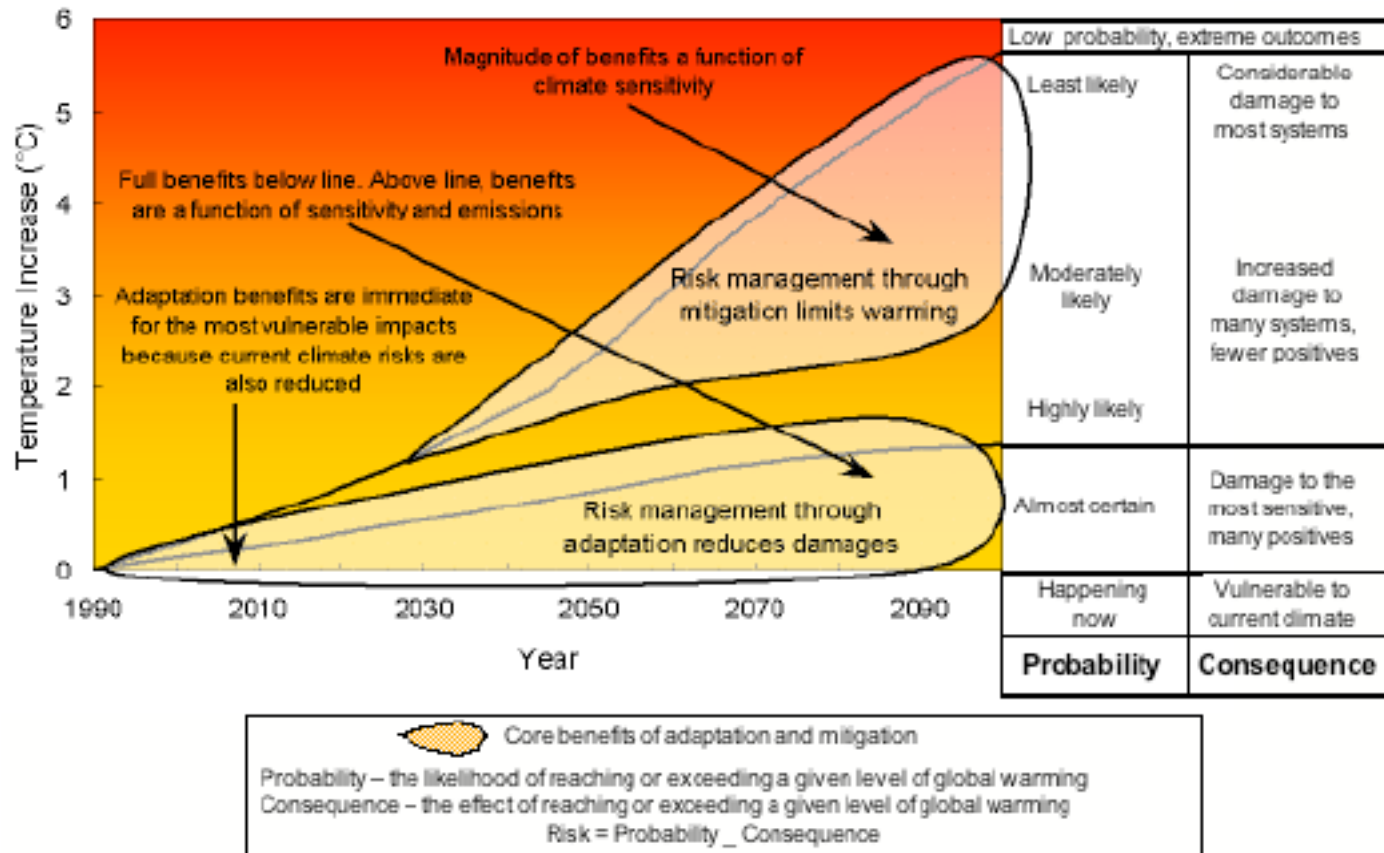
And so.....

Even though risk profiles can require enormous amounts of information (just like benefit-cost calculations), they have great potential for prioritizing short- and long-term adaptation and mitigation actions.

Recommended Reading

- Special issue of *The Integrated Assessment Journal*, Vol 8, Issue 1 (2008) - open access via the web
- Working paper by Gary Yohe, for EPA, on the risk management approach (available by request)
- Yohe, G. and Strzepek, K., “Adaptation and Mitigation as Complementary Tools for Reducing the Risk of Climate Impacts”, *Mitigation and Adaptation Strategies for Global Change*, Volume 12, Number 5 / June 2007.
- Kirshen, Paul, Chris Watson, Ellen Douglas, Allen Gontz, Jawon Lee, and Yong Tian. “Coastal flooding in the Northeastern United States due to climate change,” *Mitigation and Adaptation Strategies for Global Change*, Volume 13, Numbers 5-6 / June 2008
- Yohe, Gary, “Addressing Climate Change through a Risk Management Lens”, forthcoming from Pew Center on Climate Change.

Combining adaptation and mitigation planning in a risk management framework



Source: Jones and Yohe (2008)



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