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Climate Resilience: A new Paradigm for Buildings?

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Washington, DC - January 8th, 2019

"WE DO NOT HAVE PLANET B"

French President Emmanuel Macron, Washington, DC, 2018

☹☺

Overview

- Needed Definitions
- Climate Change (CC) manifestations (demands)
  - Preparatory background of climate change, hazards and temporal behavior
  - Applicability to civil infrastructures
  - Usefulness of resilience vs. risk
- Objective Case Studies
  - Decision model for river flooding of non-residential buildings
  - Decision models for the 100th Meridian problem
  - Risk / Resilience multihazards assessment model for Apalachicola River, Chattahoochee River, and Flint River (ACF) estuary
  - Generic decision model for river basins
- Lessons learned

Resilience-Related Definitions

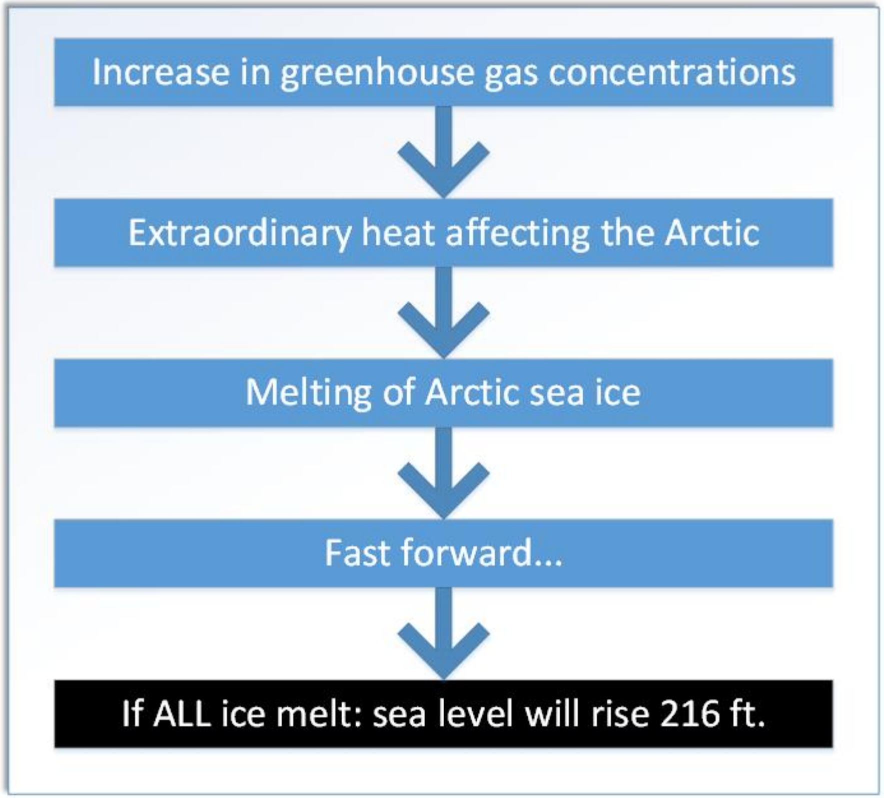
- Resilience[1]
  - the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies.
- Recovery[1]
  - those capabilities necessary to assist communities affected by an incident to recover effectively, including, but not limited to, rebuilding infrastructure systems; providing adequate interim and long-term housing for survivors; restoring health, social, and community services; promoting economic development; and restoring natural and cultural resources.
- Climate Resilience (Proposed)?
  - the ability to adapt to changing ***Climate*** conditions and withstand and rapidly recover from disruption due to emergencies.

1. PPD (2011). "Presidential Policy Directive / PPd-8: National Preparedness".

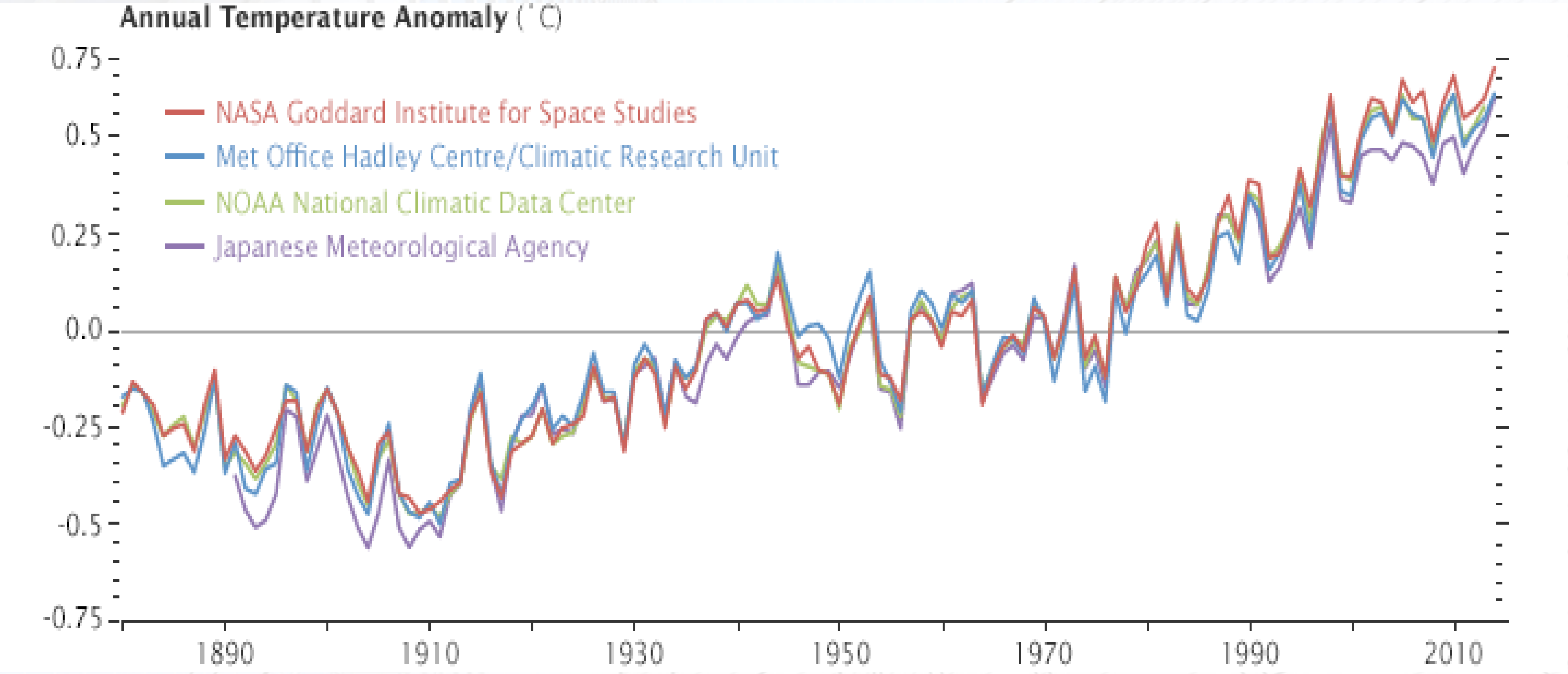
Definitions: CC & Global Warming

- climate change[1] *"a long-term change in the earth's climate, especially a change due to an increase in the average atmospheric temperature"*

1.From: Dictionary.com



Global Warming



Green house gases started affecting global temperatures since 1900s.
The leveling between WWII and 1970 is due to the aerosol effects, which, after controlling its use, was diminished, and the green house gases effects returned to dominate global temperatures.

CC Demands on Infrastructures

Simple manifestations of weather / climate

- Temperature
- Humidity
- Precipitation
- Wind
- Cloudiness
- Brightness
- Visibility
- Atmospheric pressure
- Other

Direct hazards demands (*DHD*) of weather / climate as might be experienced by civil infrastructures

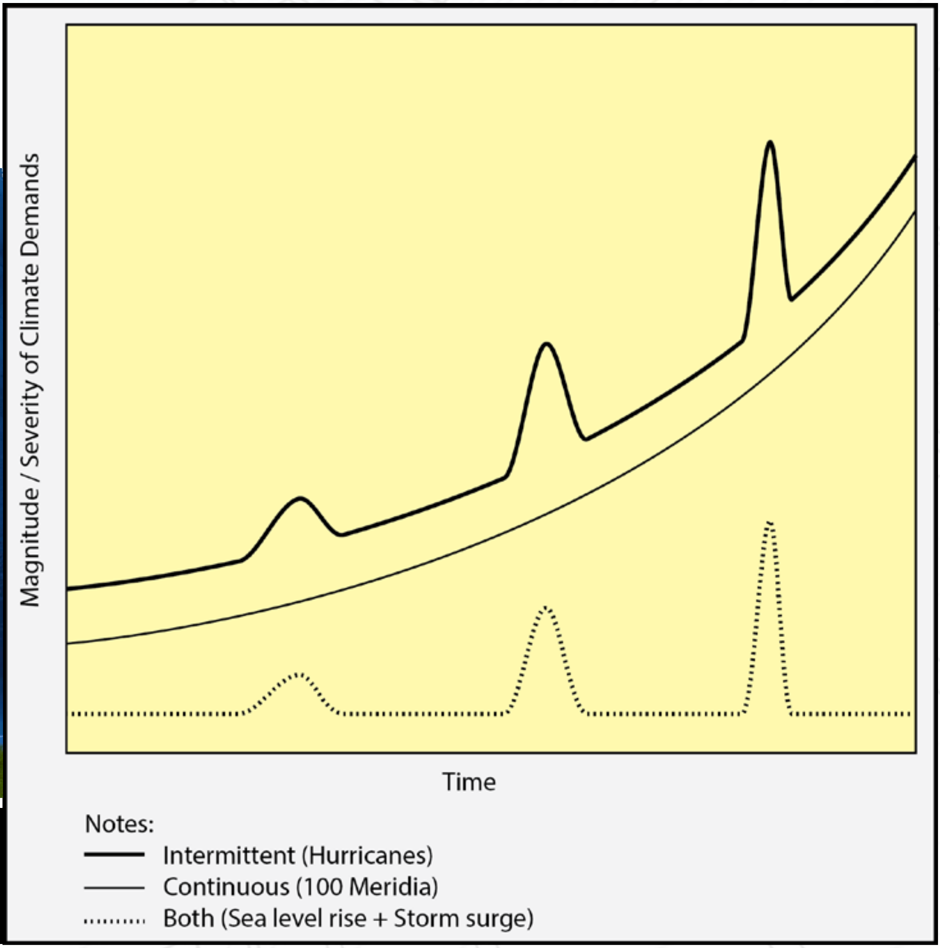
- Temperature
- Freeze / thaw
- Hurricanes
- High wind / tornadoes
- Flood
- Storm surge
- Wild fires
- Sea levels rise
- Other

By-product hazard demands (*BPHD*) resulting from *DHD*

- Over stressing – Structural deficiency
- Deterioration
- Security risk
- Scour
- Increased earth pressure
- Corrosion
- Soil slope failures
- Functional obsolescence
- Other

Temporal Types of CC Demands

How would this type distinction affect resilience applications?



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Examples-Temporal CC Demands

#	CC Demand	Temporal Characteristics
1	Rising seas / increased coastal flooding	Continuous / Intermittent
2	Longer and more damaging wildfire seasons	Intermittent
3	More destructive hurricanes	Intermittent
4	More frequent and intense heat waves	Intermittent
5	Military bases at risk	Continuous / Intermittent
6	National landmarks at risk	Continuous / Intermittent
7	Widespread forest death, e.g., Rocky Mountains	Intermittent
8	Costly and growing health impacts	Continuous
9	An increase in extreme weather events	Intermittent
10	Heavier precipitation and flooding	Intermittent
11	More severe droughts in some areas	Continuous / Intermittent
12	Increased pressure on groundwater supplies	Continuous
13	Growing risks to our electricity supply	Continuous / Intermittent
14	Changing seasons	Continuous
15	Melting ice	Continuous
16	Disruption to food supplies	Continuous / Intermittent
17	Destruction of coral reefs	Continuous
18	Plant and animal range shifts	Continuous
19	The potential for abrupt climate change	Continuous



Implications of Temporal CC Demands

<table>
<tr><th rowspan="2">Implications from Resilience Viewpoint</th><th colspan="2">CC Temporal Demand Type</th></tr>
<tr><th>Intermittent</th><th>Continuous</th></tr>
<tr><td>Prevention</td><td colspan="2">Perhaps best choice</td></tr>
<tr><td>Preparedness</td><td>Can be effective, especially using non-robustness measures</td><td rowspan="2">Can be effective in short term with diminishing ROI as time progress</td></tr>
<tr><td>Protection / Robustness</td><td>Can be effective if planned properly</td></tr>
<tr><td>Asset vs. Community treatment</td><td>Can be effective for both</td><td>Effective for assets, can be prohibitive for community</td></tr>
<tr><td>Mitigation</td><td colspan="2" rowspan="2">See Preparedness</td></tr>
<tr><td>Resource allocations / planning</td></tr>
<tr><td>Response</td><td rowspan="2">Can be effective with increasing difficulties</td><td>Long term planning effective only short term. Increasingly becomes prohibitive then impossible</td></tr>
<tr><td>Recovery</td><td>Not possible</td></tr>
</table>

Important Lesson!

Climate Change

Effective civil infrastructure paradigms

Risk

Always applicable to all manifestations of climate change

Resilience

Does not apply to all manifestations.

Since ‘recovery’ is not always possible

Measures of Resilience

- Subjective
  - Abstract
    - High, Medium, Low
  - Continuity of Operations / Subjective
    - None, Minimum, Moderate interruptions, Severe interruptions, Stoppage
- Objective
  - Continuity of Operations / Objective
    - None, Minimum, Moderate interruptions, Severe interruptions, Stoppage
  - Time to Complete Recovery
    - Measured in objective temporal units (minutes, hours, days, months, etc.)
  - Monetary
    - Measured in monetary units
    - In such a situation, ***Resilience becomes another manifestation of risk***

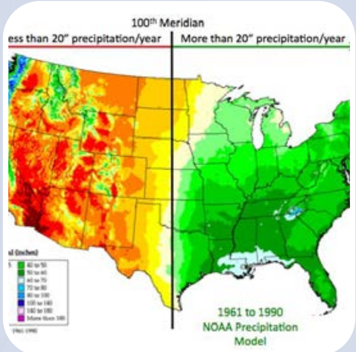
Our Objective Tool

- We use a Probabilistic Graph Network (PGN)
  - Bayesian (or Markov) network
  - Decision model
- PGN is eminently suitable for the study of climate change effects since
  - It is probabilistically based, from grounds up
  - The links and dependencies of different parameters are built in
  - Adding, or removing parameters from the model can be done easily
  - More importantly, the changes in different variables as resulting from changes in climate can easily be enumerated, without having to make major changes in the objective model
  - Can be integrated easy with decision models
- We will use PGN as a basis for all our case studies, with varying details

Steps for Building a PGN

- Building a resilience decision model
  - Define controlling issues
  - Define available decisions (to business / building owner)
  - Establish links
  - Establish conditional probabilities
  - Establish costs for different decision
  - Solve the probabilistic influence diagram (ID) model
  - Find optimal decision to proceed

Objective Case Studies



- Decision model based on resilience of non-residential buildings due to river flooding
- Decision model for 100^{th} Meridian problem
- Risk / Resilience model for ACF estuary (Multihazards problems resulting from climate change)
- Generic (Risk or resilience) decision model for river basin

Case Study: River Flooding – 1

River Flooding – 2

- CC-related causes
  - Frequent (changing return period) and more intense precipitation
  - Higher ground water levels
  - Melting snows and ice
- Consequences for assets / communities
  - Scour
  - Failure / degradation of infrastructure / lifelines
  - Difficulties in response / recovery efforts
  - Disruptions to community operations

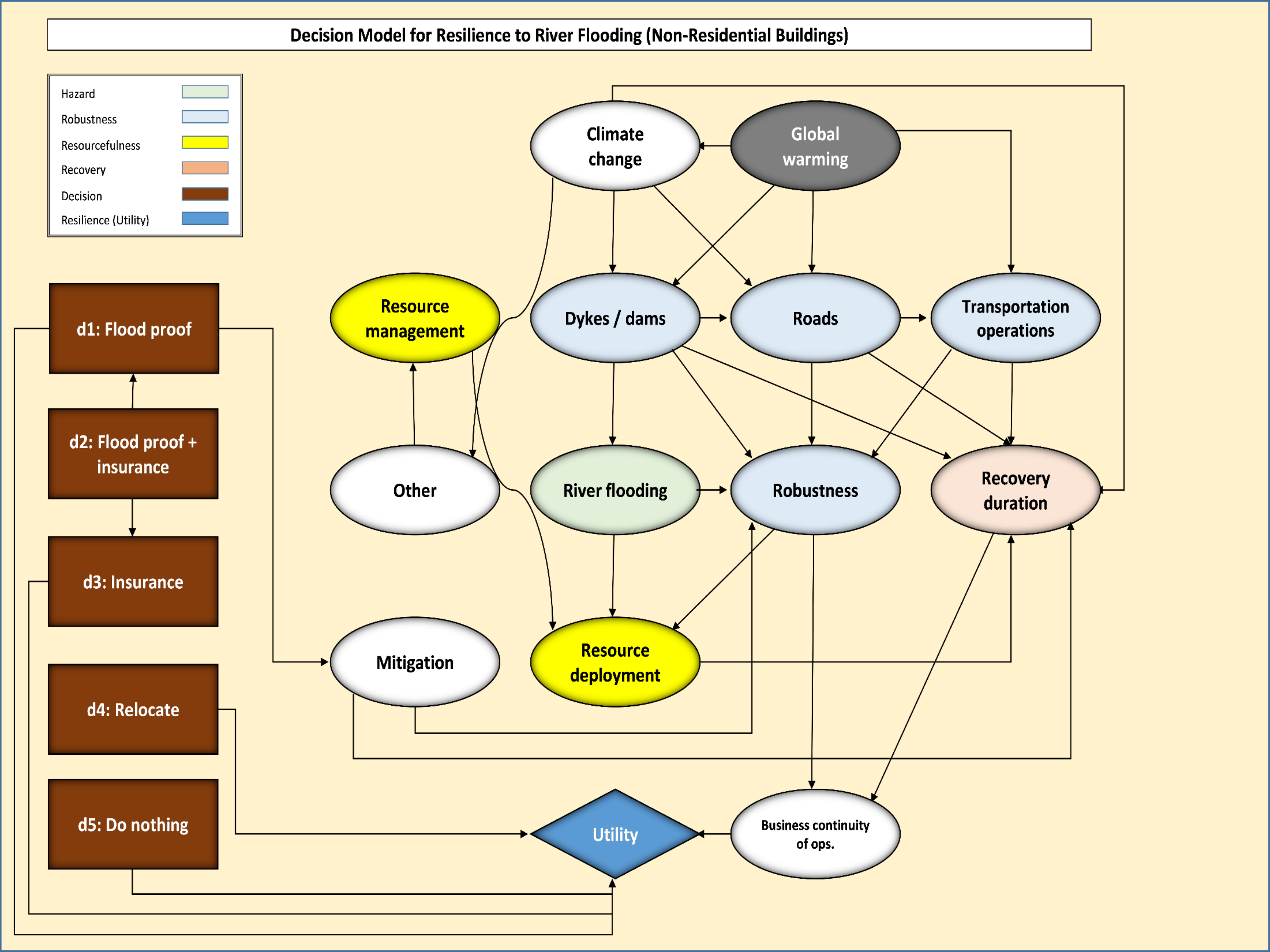
River Flooding Decision Paradigms

(Non-Residential Buildings)

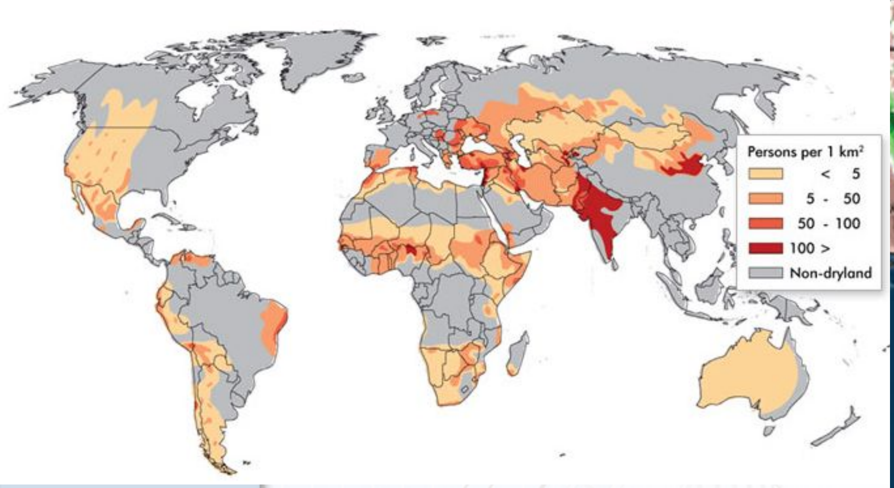
Issues	Decision Paradigm		
	Resilience	Reliability	Risk
Prevention	Partial: while resilience improve COOP, risk adds increasing economic versatility		
Preparedness	Partial: physical, COOP	Partial: physical	Partial: physical, COOP, economic
Protection / Robustness	Yes		
Asset vs. Community treatment	Asset + community	Usually asset-based	Asset + community
Mitigation	See Preparedness		
Resource allocations / planning	physical, COOP	No	physical, COOP, economic
Response			
Recovery			

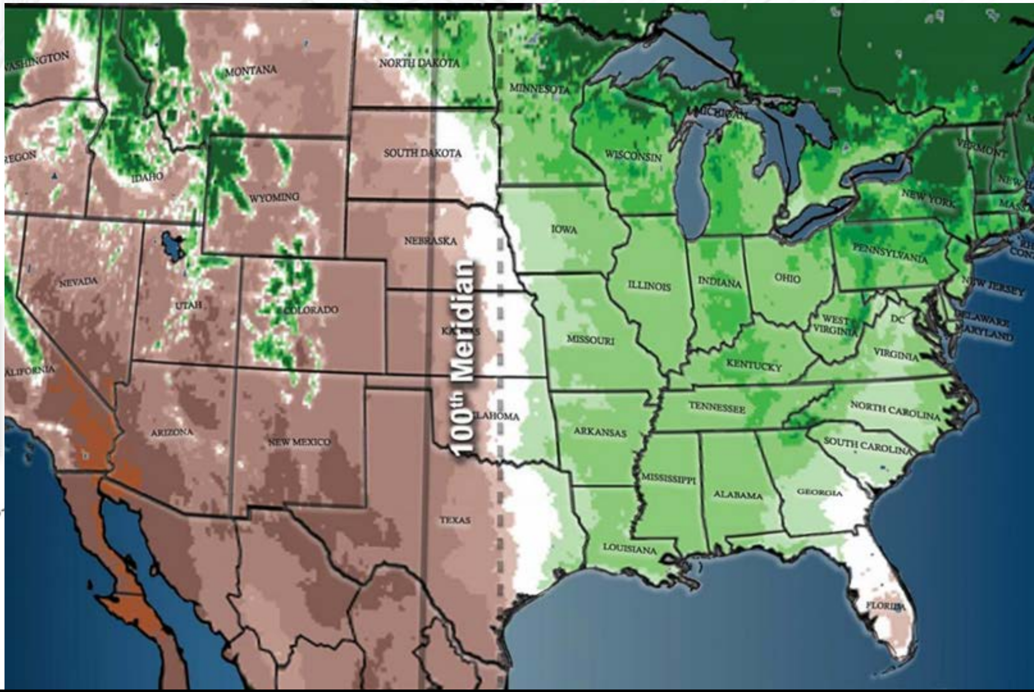
Define available decisions

- D1: Flood proof the building (includes several sub-decisions)
  - Minimum code requirements (ASCE 24 / FEMA P-936 / etc.)
  - Different higher performance levels, in anticipation of more demand due to climatic change
  - Improve resource management / recovery operations / coordination
- D2: Combination of flood proofing and insurance
- D3: Insurance only
- D4: Relocate the business
- D5: Do nothing


Decision Model for Resilience to River Flooding (Non-Residential Buildings)
Hazard
Robustness
Resourcefulness
Recovery
Decision
Resilience (Utility)
Climate change
Global warming
Resource management
Dykes / dams
Roads
Transportation operations
d1: Flood proof
d2: Flood proof + insurance
Other
River flooding
Robustness
Recovery duration
d3: Insurance
Mitigation
Resource deployment
d4: Relocate
d5: Do nothing
Utility
Business continuity of ops.

Case Study: 100th Meridian– 1





-100th meridian divides the North American continent into arid western regions and humid eastern regions

-There is an east–west gradient in aridity roughly at the 100th meridian

-The gradient arises from atmospheric circulations and moisture transports.

100th Meridian – 2

- CC-related causes
  - Climate-related changes in wind and moisture flow in both summer and winter from Atlantic, Pacific and Gulf regions.
- Consequences for assets / communities
  - Soil moisture / ground water levels
  - West to east transition from short grass to tall grass prairie
  - Transition from coverage of developed land (east to west)
  - Lower farm productivity
  - Changes in water-resource infrastructure

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100th Meridian – 3

Physical Consequence	Socio-Economic Consequence	Civil Infrastructure Ramification
• Lower availability of water in a natural way	Change irrigation systems	Building different irrigation system
	Change crops, e.g.	May require different infrastructure for: • Storing • Moving
	Less available supply water for urban areas	New infrastructure for • Water management • Efficient water usage • Re-distribution of water resources • Waste management
	Consolidations of smaller farms to larger ones	New infrastructure for larger, more consolidated production volumes
	Avoid farming to more viable products, e.g., cattle grazing	New infrastructure for handling the different types of products
• Higher temperature	Adjustments of all aspects of life	• Design / construction / operations of habitats

- Note that the above is all about
  - Adaptation / costs
- Not
  - Mitigation / recovery

This is Risk, not Resilience!

100th Meridian Decision Paradigms

<table>
<tr><th rowspan="2">Issues</th><th colspan="3">Decision Paradigm</th></tr>
<tr><th>Resilience</th><th>Reliability</th><th>Risk</th></tr>
<tr><td>Prevention</td><td colspan="3">Limited capability</td></tr>
<tr><td>Preparedness</td><td colspan="2">Limited potential</td><td rowspan="7">Possible (based on asset, community, costs and economics)</td></tr>
<tr><td>Protection / Robustness</td><td rowspan="5">Fairly limited</td><td rowspan="6">No</td></tr>
<tr><td>Asset vs. Community treatment</td></tr>
<tr><td>Mitigation</td></tr>
<tr><td>Resource allocations / planning</td></tr>
<tr><td>Response</td></tr>
<tr><td>Recovery</td><td>No</td></tr>
</table>

Objective Example:

Decision Model for a Small Community

- The model should be about adaptability / costs
  - Not recovery or continuity of operations
  - ***Since 'recovery' is NOT feasible ☹***
  - Build decision-making models
  - Find optimal decision to proceed

- Since it can't be cast as a recovery (Resilience) issue, it should be cast as a risk decision-making problem

Define available decisions (and their costs)

Urban / Rural decisions

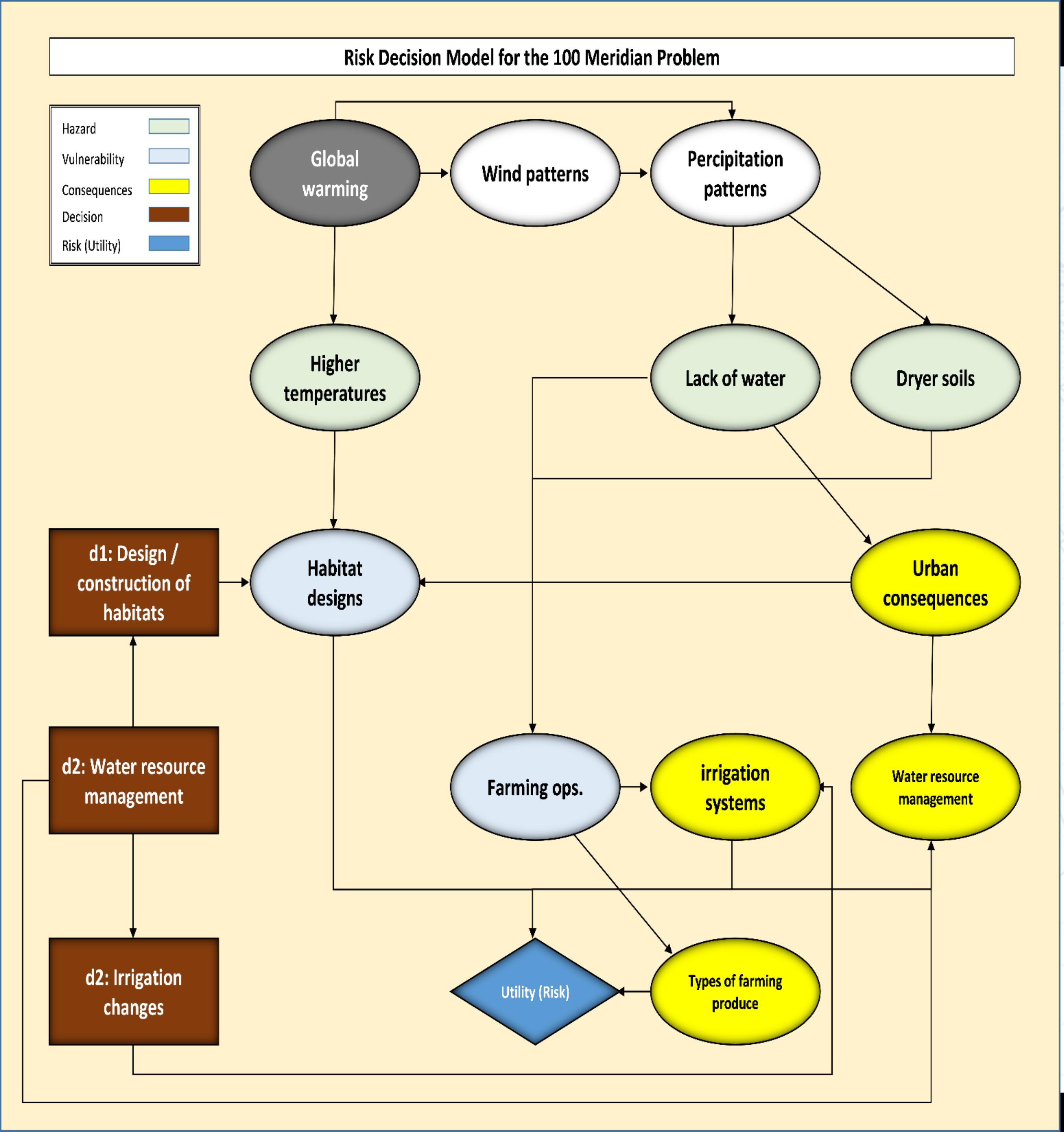
- Changes needed in design / construction to meet higher temperature demands
  - Residential / business farming / roadways, etc.
- Changes needed in water resource management

Farming operations

- Changes needed in farming production
  - Crops
  - Life stock
- Changes needed in farming irrigation systems

Unfeasible decisions

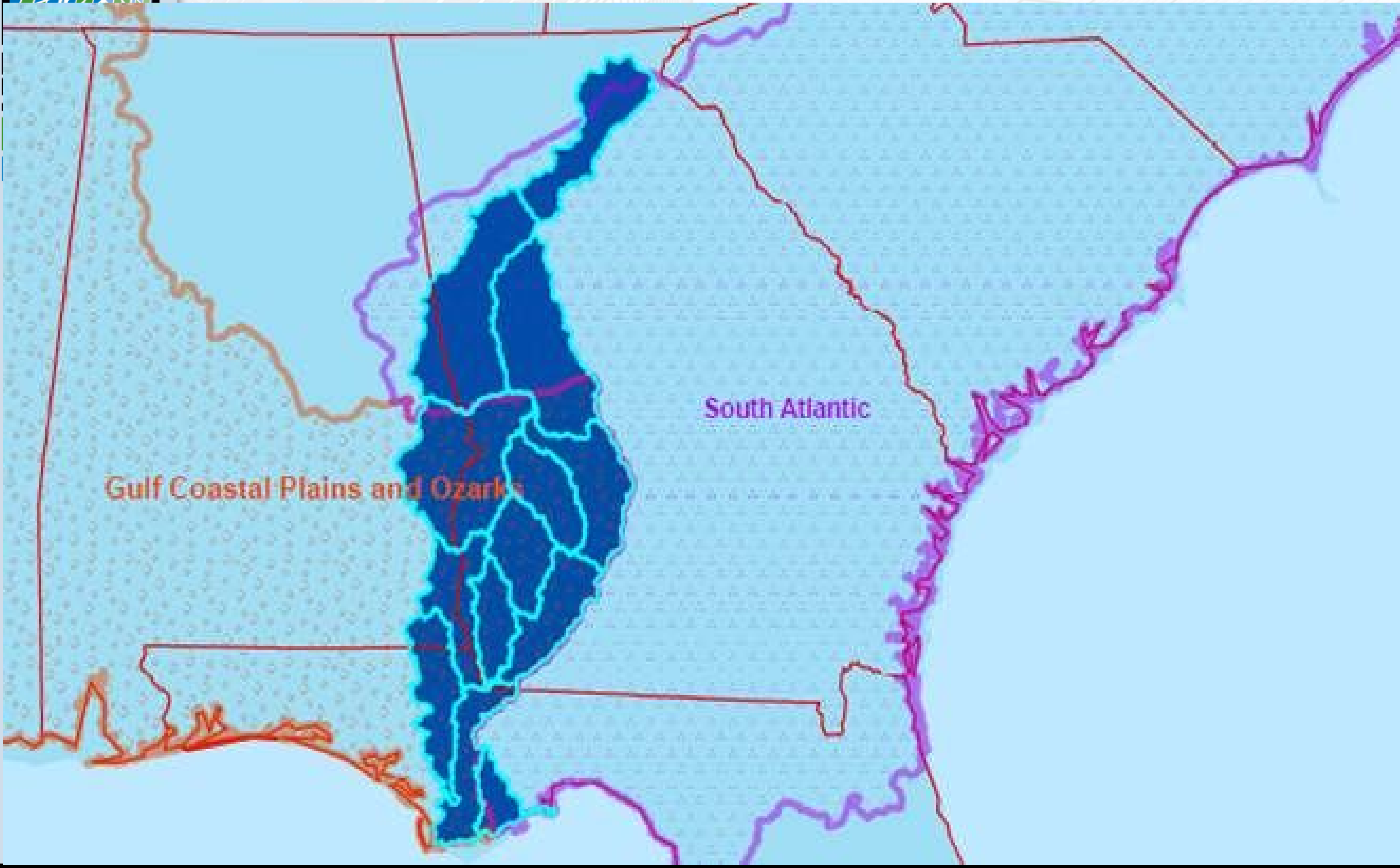
- Do nothing
- Transfer risk (insurance)



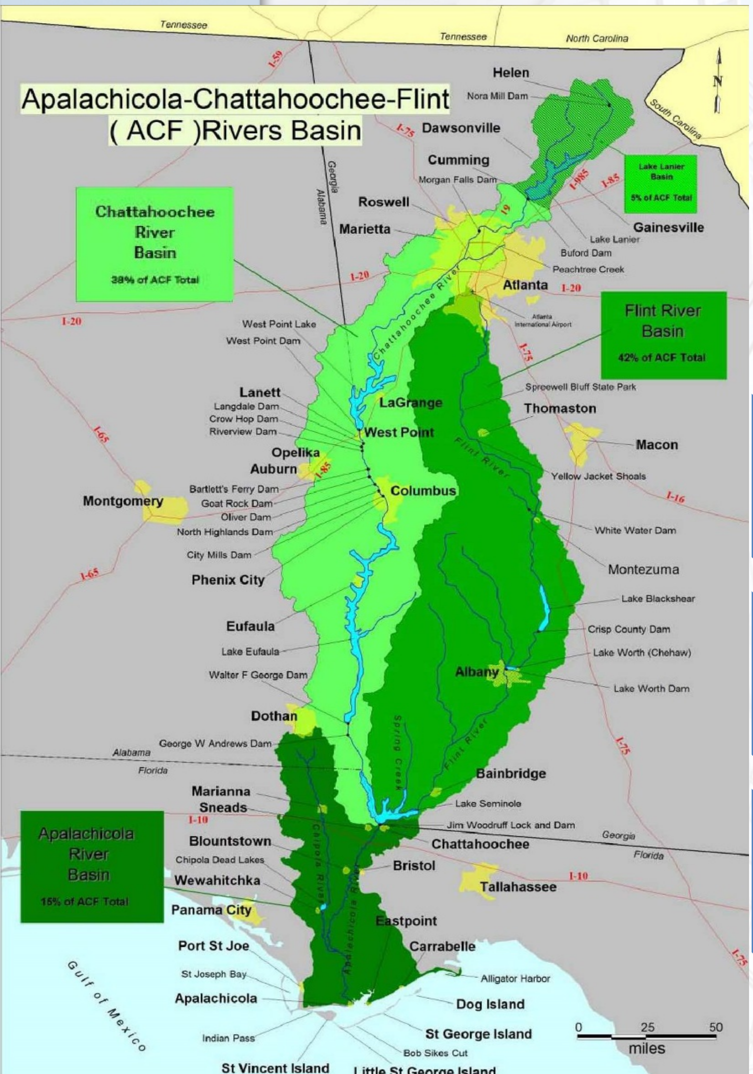
The decisions in this model are fairly general

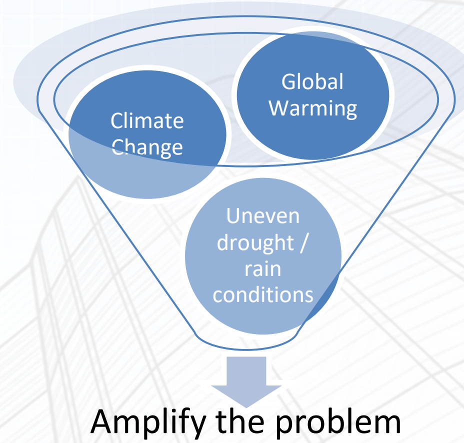
More detailed decisions are needed for practical situations

Case Study: MH Problems for ACF River Estuary



Case Study: MH Problems for ACF River Estuary





Excessive water use

- Rapid urban development upstream
- Agricultural needs throughout the basin

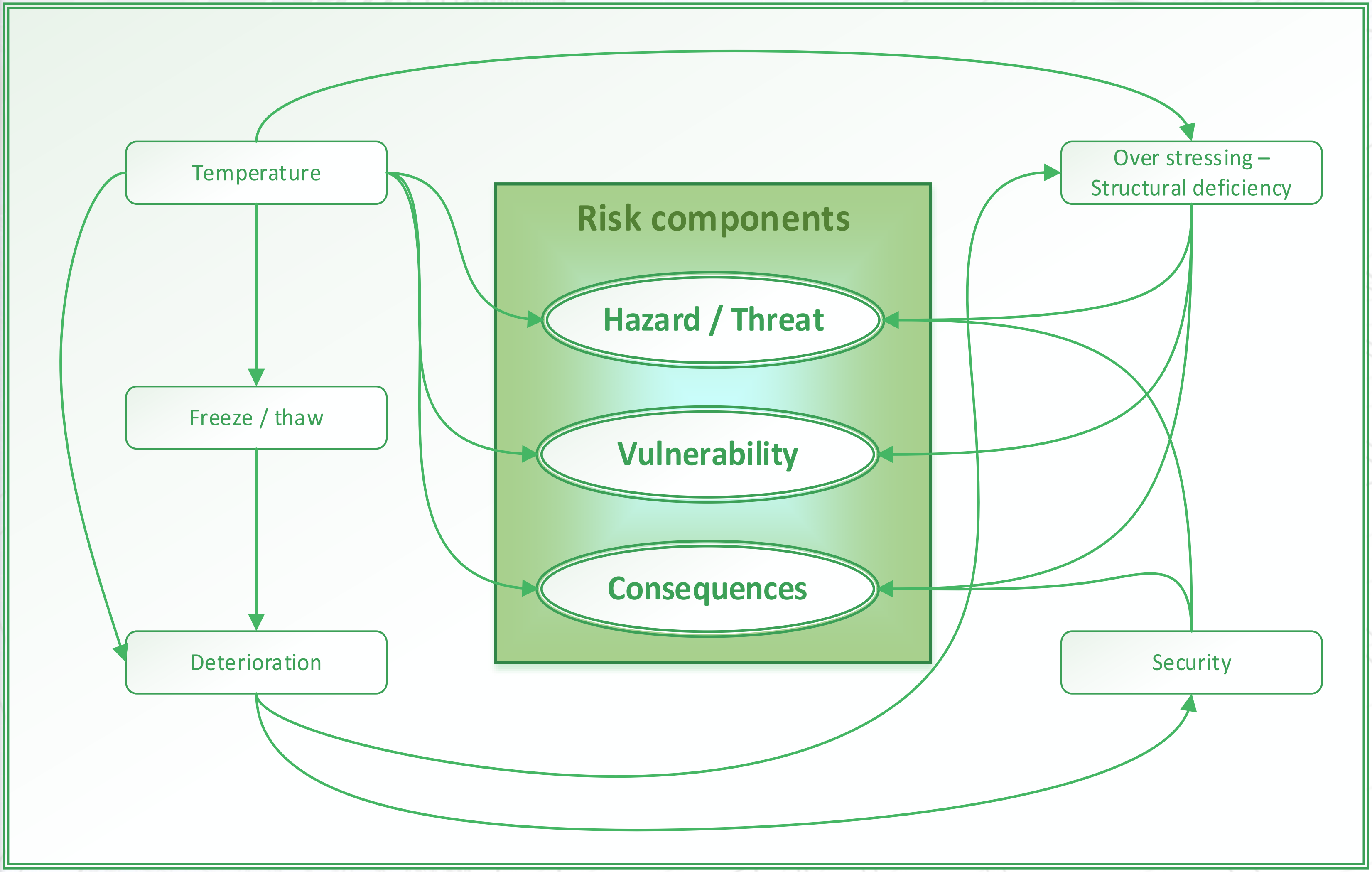
Water resource mismanagement

- Difficulties in accommodating conflicting demands
- Drought-conditions –based decisions limiting flow downstream

Estuaries needs

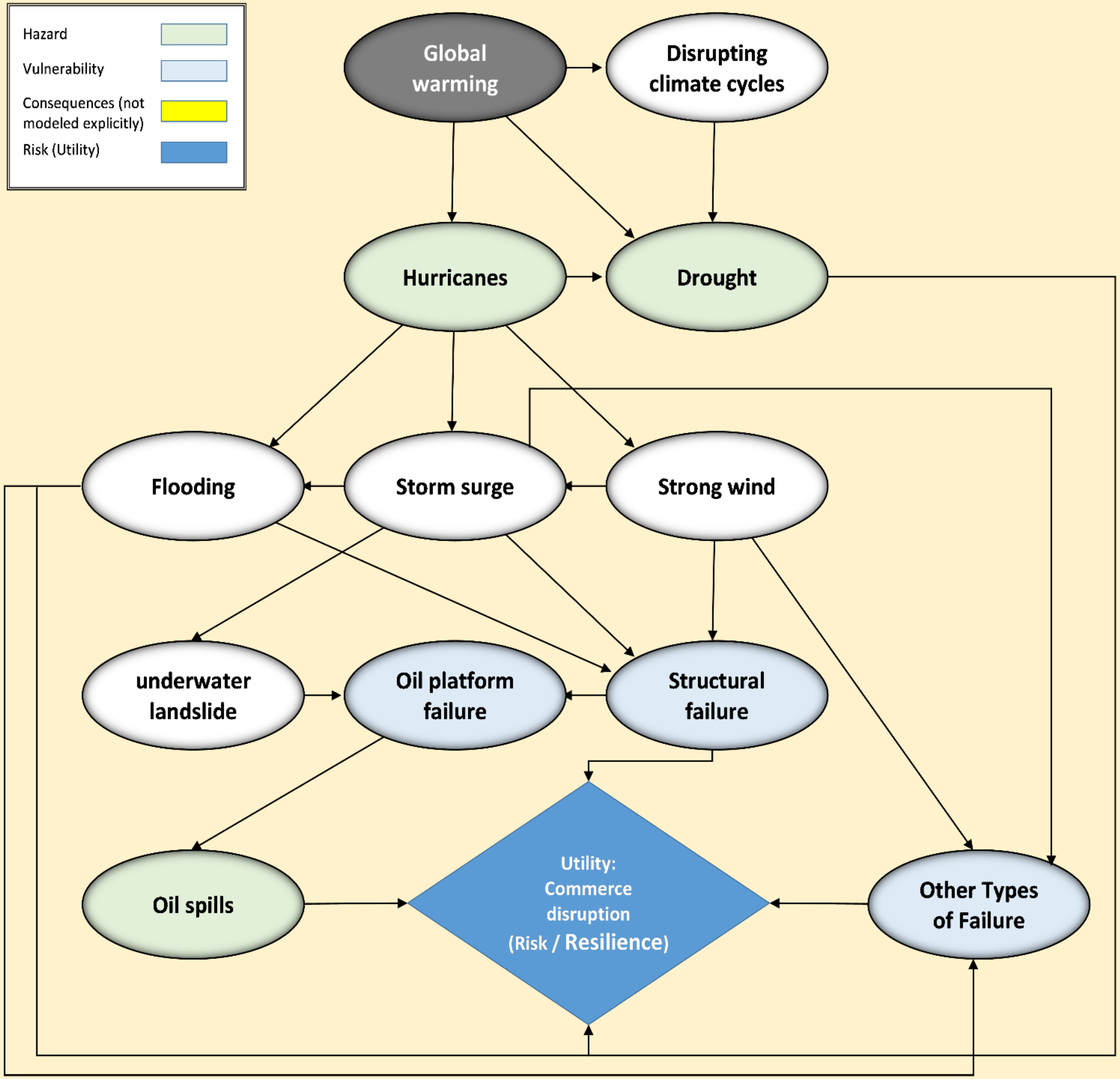
- Needs of water flow for fisheries at the bay have not met, thus impacting economies of fishing downstream

CC Risk- & MH-Related Example



Note how CC FORCES Interaction of an otherwise independent hazards!

Climate Change: Risk / Resilience Models for Multihazards Demands in Community at River Estuary



This model can be adjusted to accommodate risk to the community or the resilience of the community

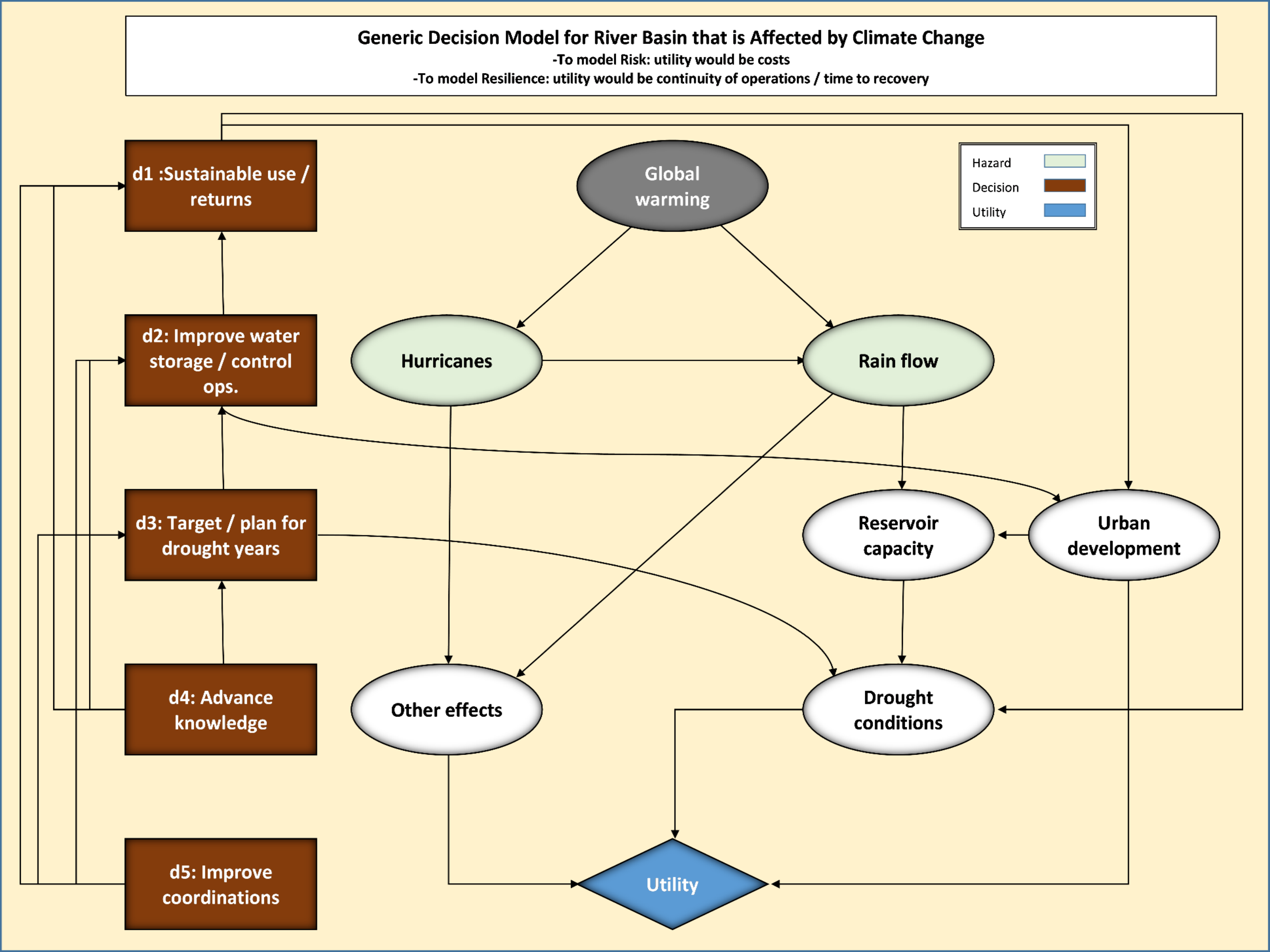
Decisions can easily be added to the model, as pertinent

(by 'community', we mean the community of the river estuary)

Case Study: Climate Change and River Basins

River basins can be affected greatly by climatic changes due to the multitude of hazards, stakeholders, consequences, and economies that intersect with it

A linked / network approach which accommodate most (if not all) important issues is thus needed for accurate assessment and decision making


Generic Decision Model for River Basin that is Affected by Climate Change
-To model Risk: utility would be costs
-To model Resilience: utility would be continuity of operations / time to recovery
Hazard
Decision
Utility
d1 :Sustainable use / returns
d2: Improve water storage / control ops.
d3: Target / plan for drought years
d4: Advance knowledge
d5: Improve coordinations
Global warming
Hurricanes
Rain flow
Reservoir capacity
Urban development
Other effects
Drought conditions
Utility

Important lessons learned

- Climate resilience, as a response to CC, requires different treatment than resilience from non-CC –related events
- There are two distinct temporal CC-related demands
  - This will necessitate different Climate resilience management strategies
    - With the correlating objective processes, of course!
- In several situations, resilience paradigm is NOT an effective, even not possible, approach to manage climate change demands!
  - Risk and MH processes are needed.

- PGN modeling is convenient for modeling risk / resilience assessment as well as related decision making processes

- Introduced four climate change related case studies
  - We also showed important details of the objective modeling of those situation for assessment and decision making