Metropolitan Water Reclamation District of Greater Chicago

Welcome to the November Edition of the 2021 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- All attendees' audio lines have been muted to minimize background noise.
- A question and answer session will follow the presentation.
- Please use the "Chat" feature to ask a question via text to "All Panelists."
- The presentation slides will be posted on the MWRD website after the seminar.
- This seminar has been approved by the ISPE for one PDH and approved by the IEPA for one TCH. Certificates will only be issued to participants who attend the entire presentation.

DR. THOMAS A. WALL
PROGRAM LEAD, ENGINEERING & APPLIED RESILIENCE
ARGONNE NATIONAL LABORATORY

Dr. Wall is the Program Lead for Engineering & Applied Resilience in the Decision and Infrastructure Sciences Division at Argonne National Laboratory, a multidisciplinary science and engineering research center of the U.S. Department of Energy. Tom co-leads Argonne's efforts in Climate and Energy Action, which is a collaboration among Argonne scientists, engineers, and external partners providing expertise in climate science and modeling, advanced computing, infrastructure risk and resilience analysis, and decision science to solve national climate resilience problems. This collaboration provides actionable climate impact information that enables industry, the engineering and planning communities, and state and local governments to proactively address climate resilience concerns in their infrastructure and community systems; recent industry partners include AT&T, PG&E, and the New York Power Authority.

NOVEMBER 17, 2021

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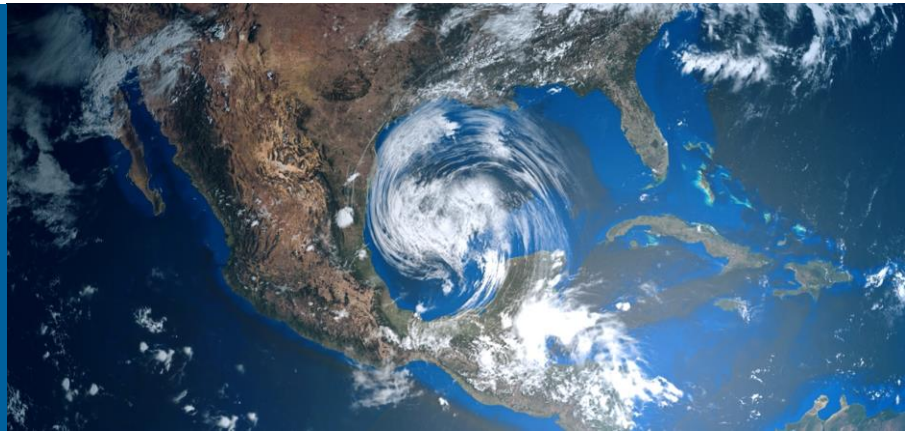
PLANNING FOR RESILIENCE WITH REGIONAL CLIMATE MODELING



THOMAS A. WALL, PH.D.
Senior Infrastructure & Preparedness Analyst
Decision and Infrastructure Sciences Division

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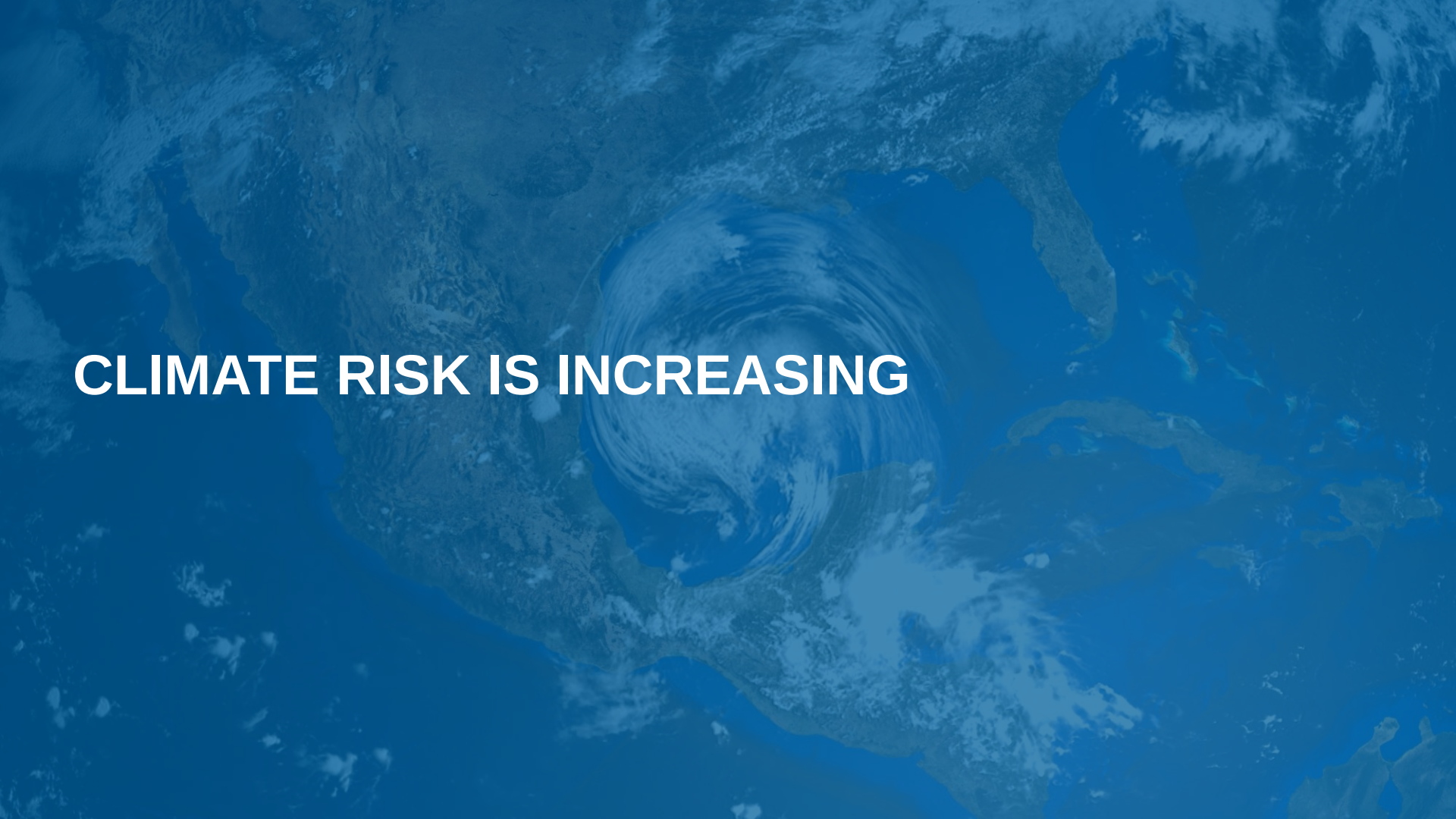
PLANNING FOR RESILIENCE

CLIMATE RISK IS INCREASING

RESILIENCE DEMANDS INFORMATION ALIGNED WITH THE SCALES AND TYPES OF DECISIONMAKING

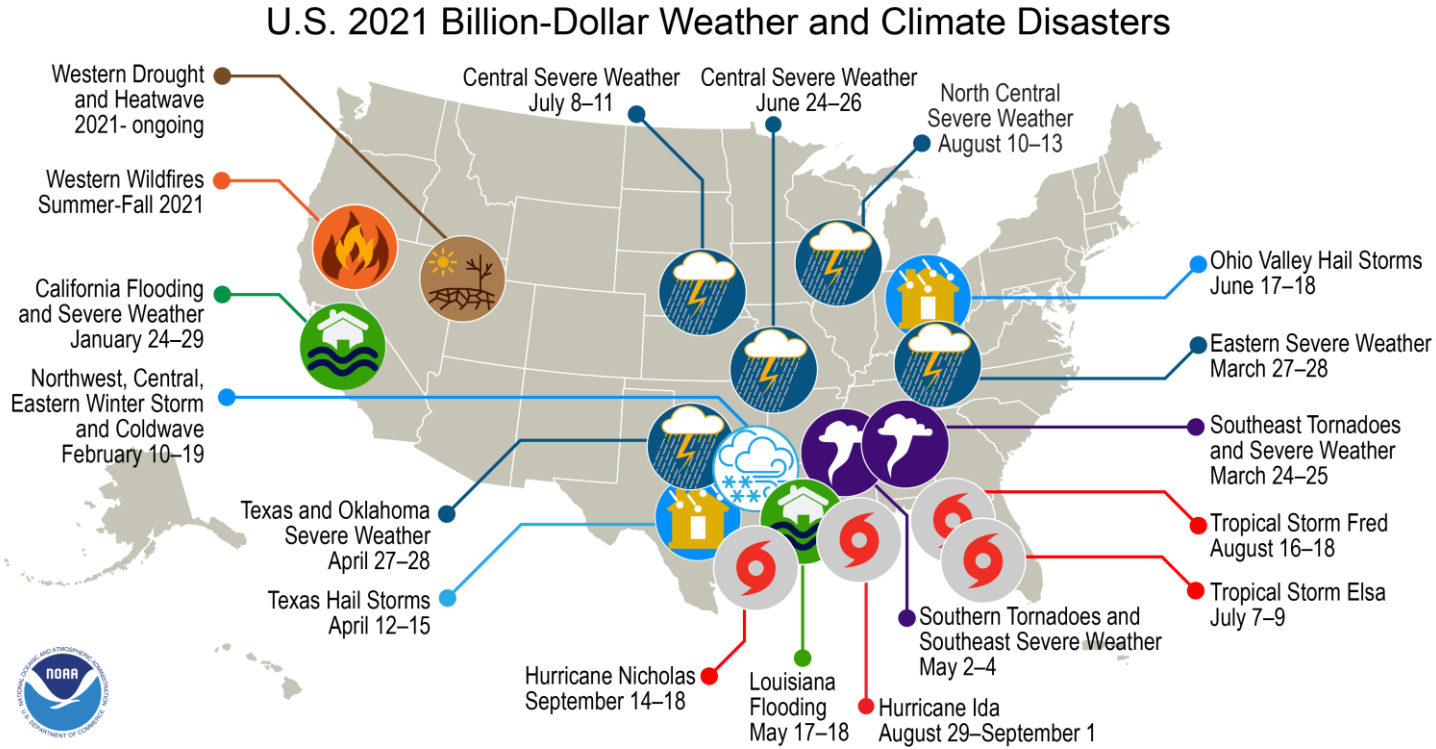
DATA INFORMS DECISION

UNCERTAINTY, RESILIENCE, AND DECISIONS



CLIMATE RISK IS INCREASING

2021 BILLION-DOLLAR CLIMATE DISASTERS: $104.8 BILLION



*This map denotes the approximate location for each of the **18 separate billion-dollar weather and climate disasters that impacted the United States January–September 2021**.*

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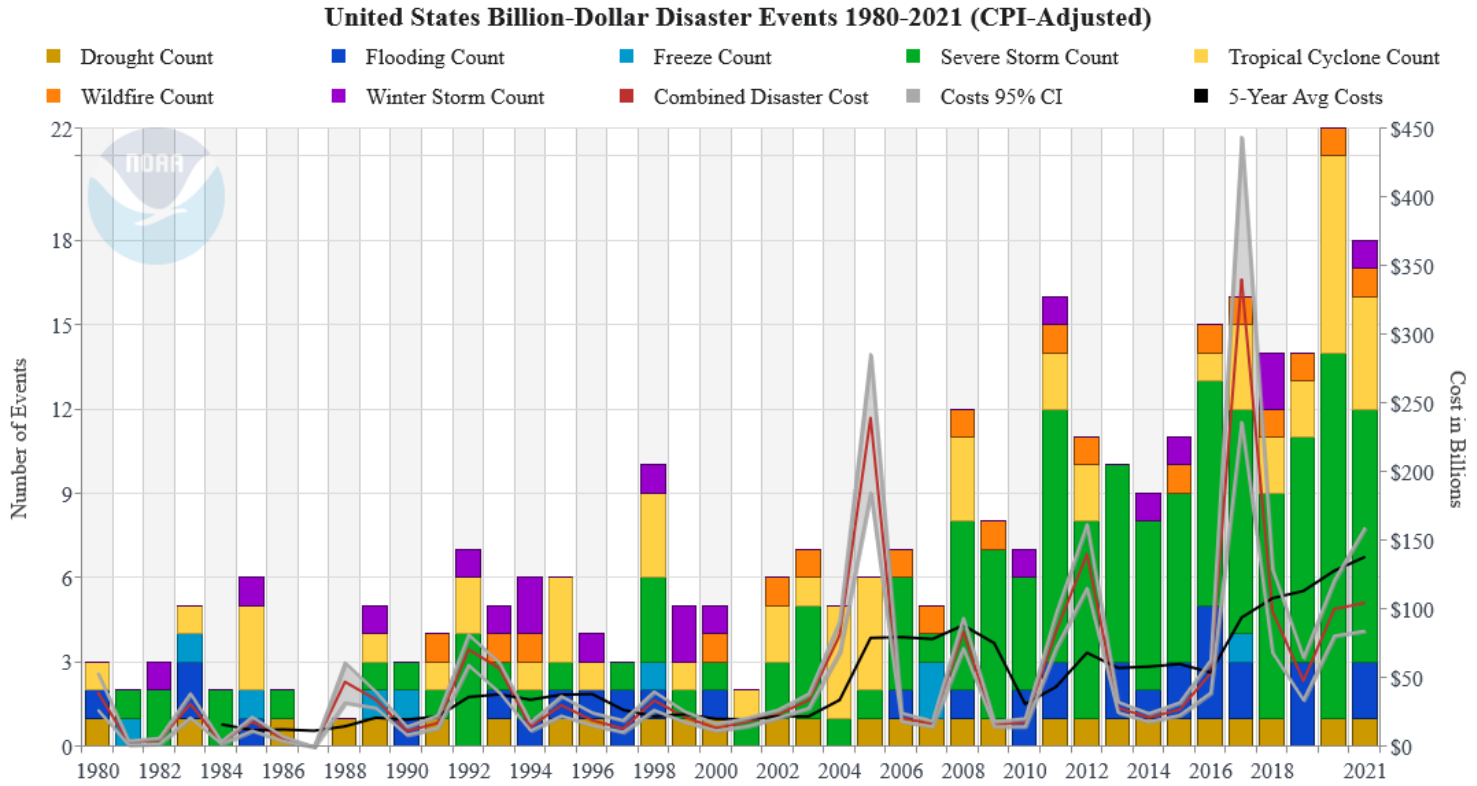
U.S. BILLION-DOLLAR DISASTER EVENT FREQUENCY



Updated: October 8, 2021

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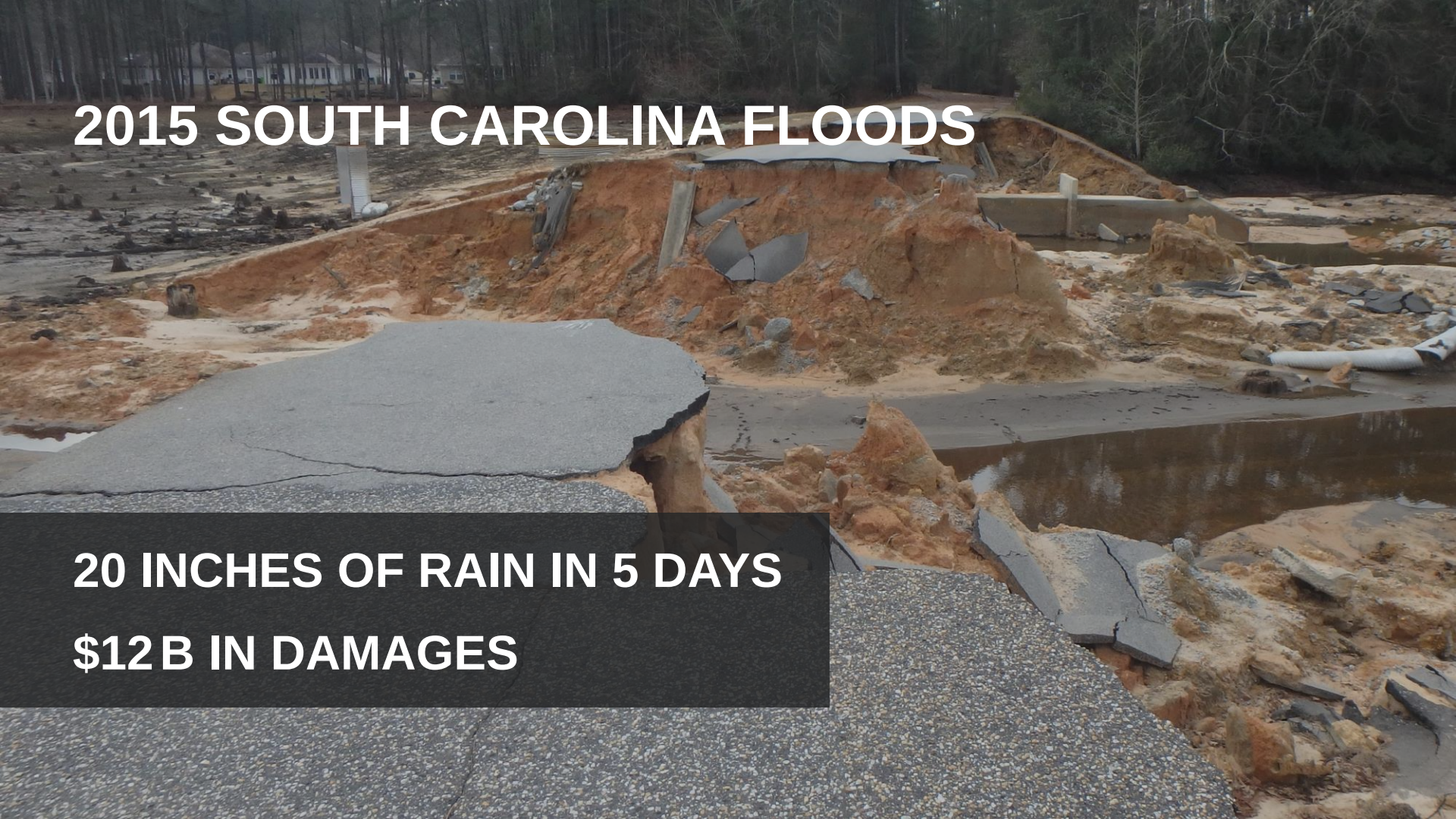
2017 HURRICANE HARVEY
60 INCHES OF RAIN
$125 B IN DAMAGES
Wikipedia

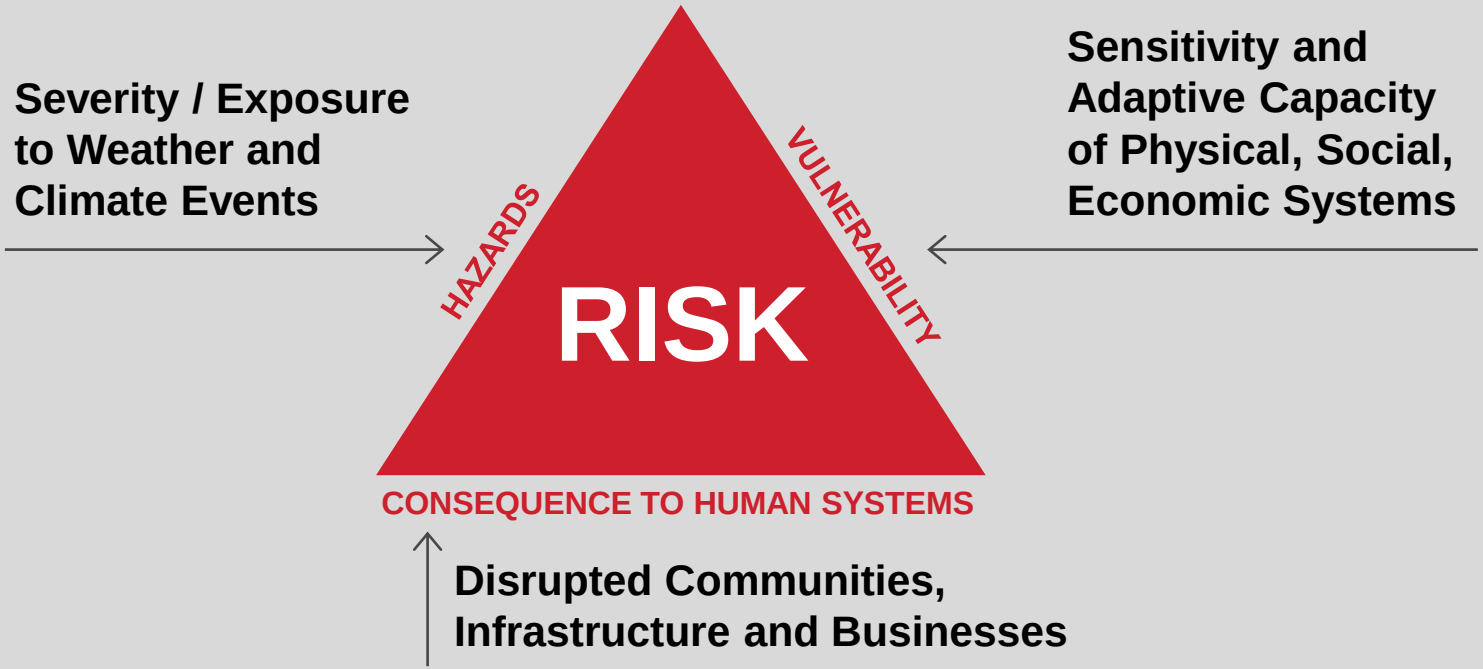


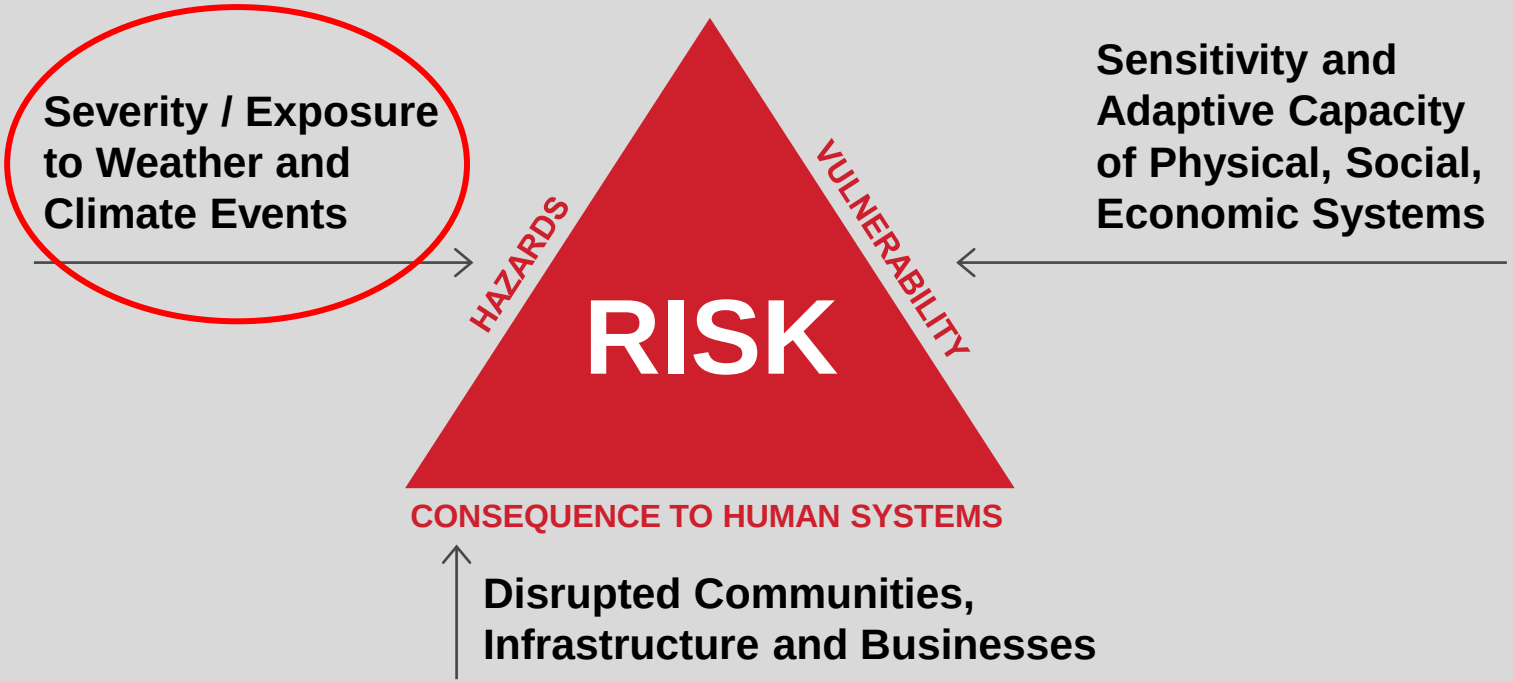
2015 SOUTH CAROLINA FLOODS

20 INCHES OF RAIN IN 5 DAYS

$12 B IN DAMAGES


2013 COLORADO FLOODS
17 INCHES OF RAIN IN 2 DAYS
$4B IN DAMAGES


Severity / Exposure to Weather and Climate Events
HAZARDS
RISK
VULNERABILITY
Sensitivity and Adaptive Capacity of Physical, Social, Economic Systems
CONSEQUENCE TO HUMAN SYSTEMS
Disrupted Communities, Infrastructure and Businesses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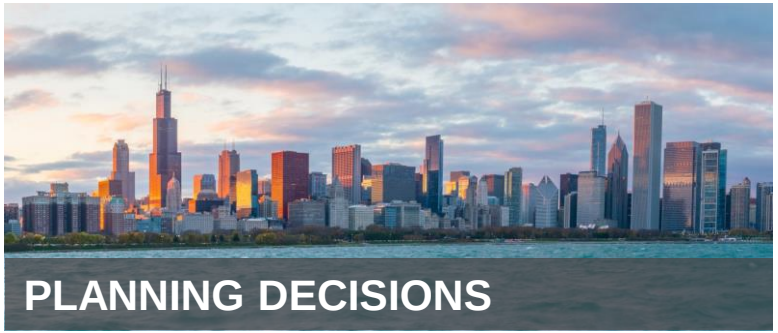
RESILIENCE DEMANDS INFORMATION ALIGNED WITH THE SCALES AND TYPES OF DECISIONMAKING

DIFFERING NEEDS IN DECISIONMAKING



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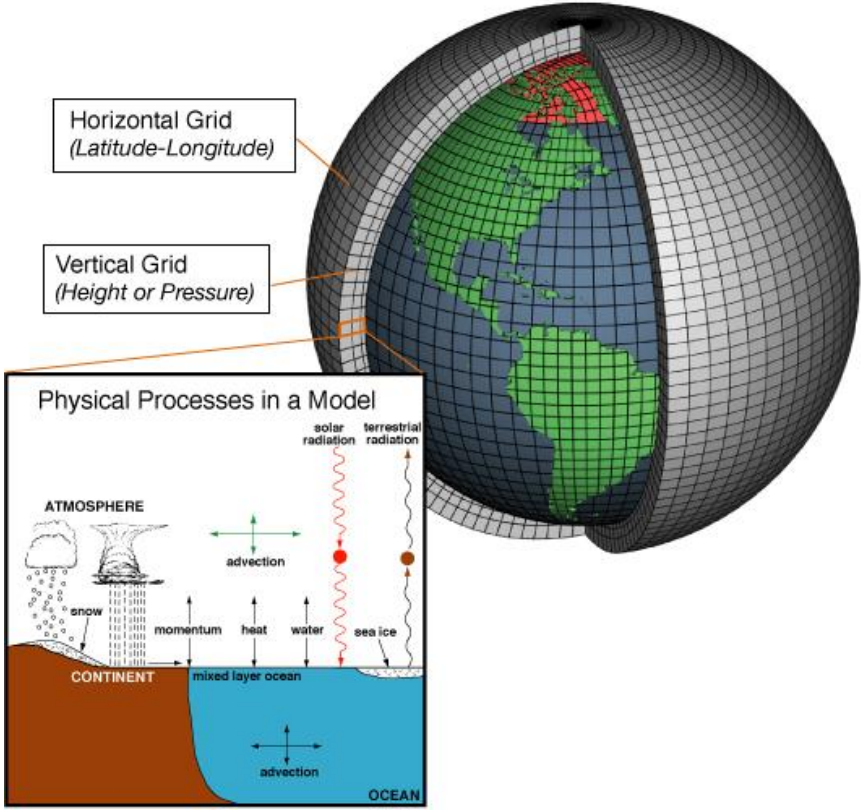
GLOBAL CLIMATE SYSTEM MODELS

Mathematical representations of the climate system based on physical laws and understanding of processes



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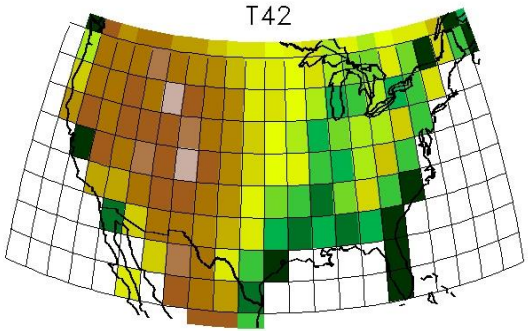
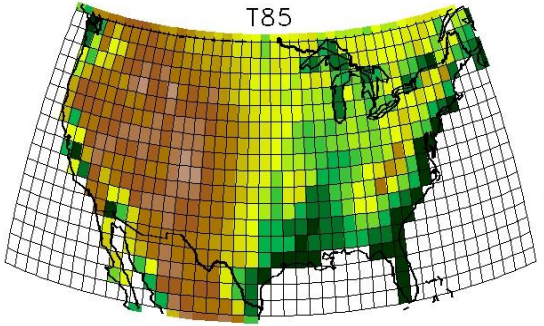
EVOLUTION OF CLIMATE MODEL RESOLUTION

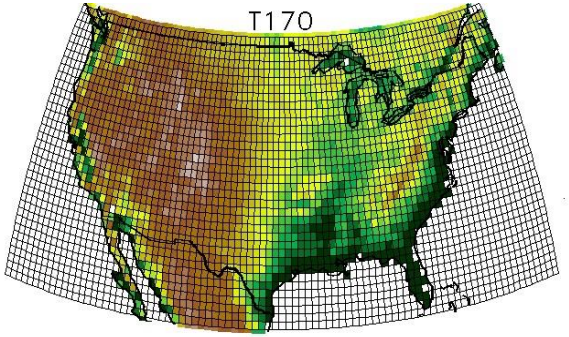
Smaller grid squares or "pixel sizes" enable more *place-specific* and *detailed* projections of locally relevant climate



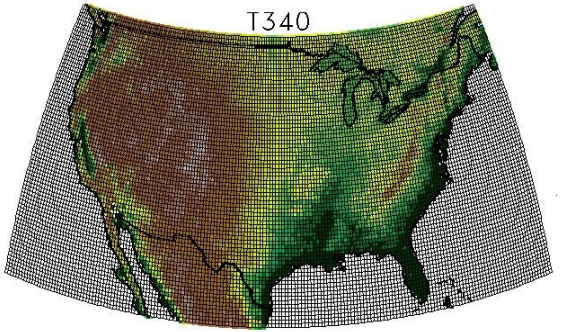
Mid-1990s 200~300 kms



2000s 100~150 kms



Current 50~100 kms



Future. 25~40 kms

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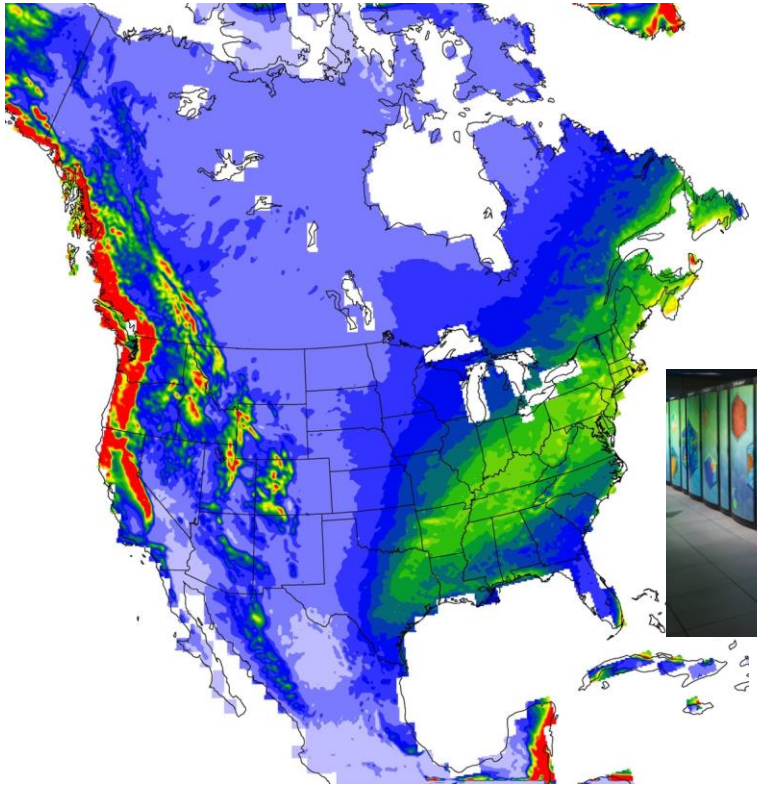
DYNAMIC DOWNSCALING

RUNS A REGIONAL CLIMATE MODEL OVER A SMALLER SPATIAL DOMAIN USING INPUT FROM GLOBAL CLIMATE MODELS

- Covers (nearly) all of North America
- Spatial resolution: 12 km
- Physics-based Model: Weather Research Forecast (WRF) Model, V3.3.1
- Output data interval 3-hrs; 8.8 GB/day
- More than 330 years of model simulation output
- Dataset size: > 700Tb
- Accounts for 2 IPCC scenarios RCP4.5, RCP8.5
- Output includes 6-8 ensemble member datasets



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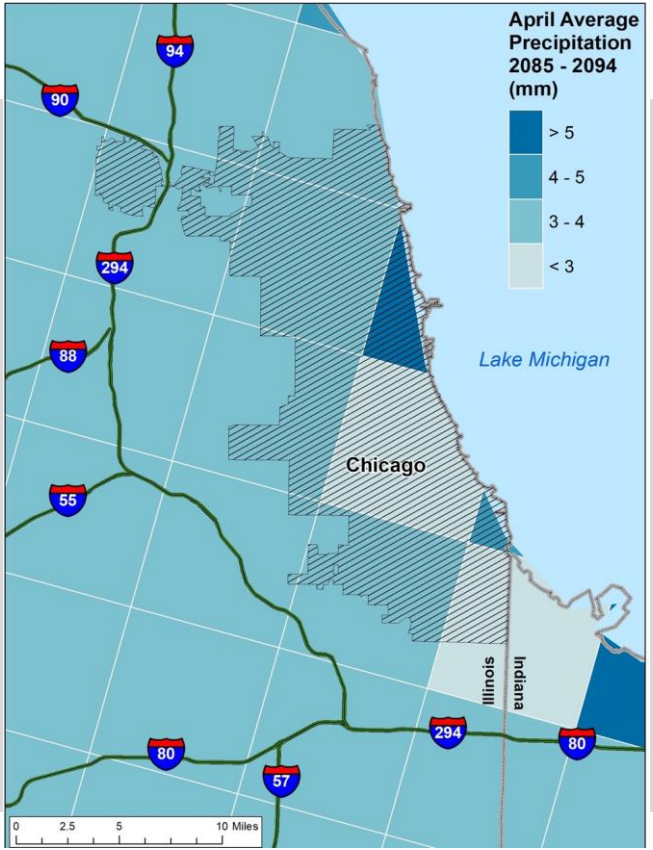

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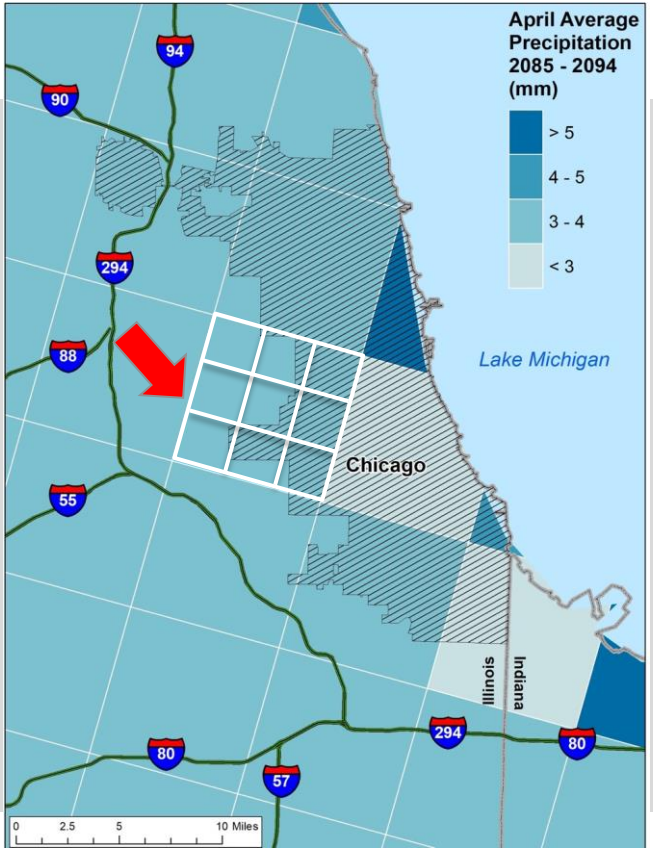

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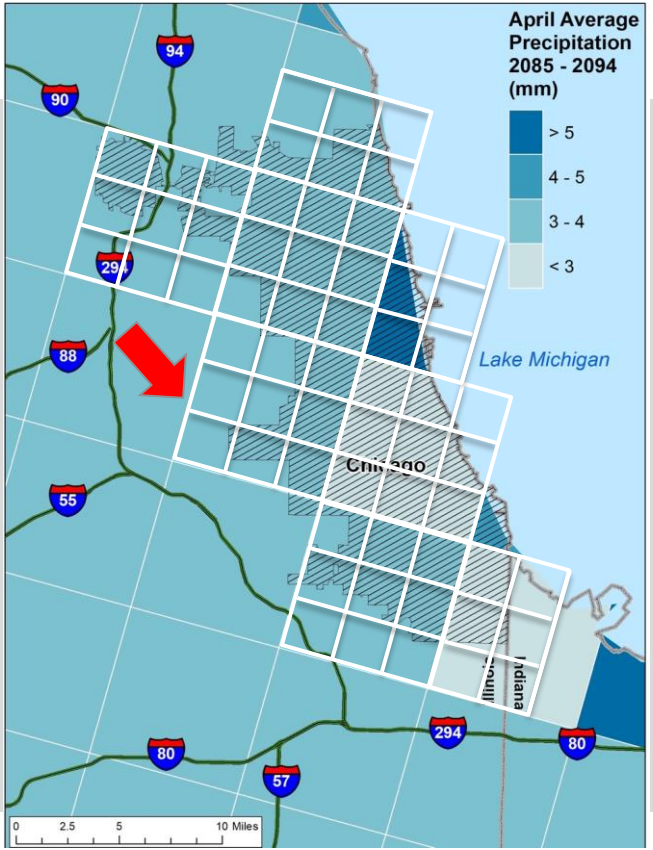
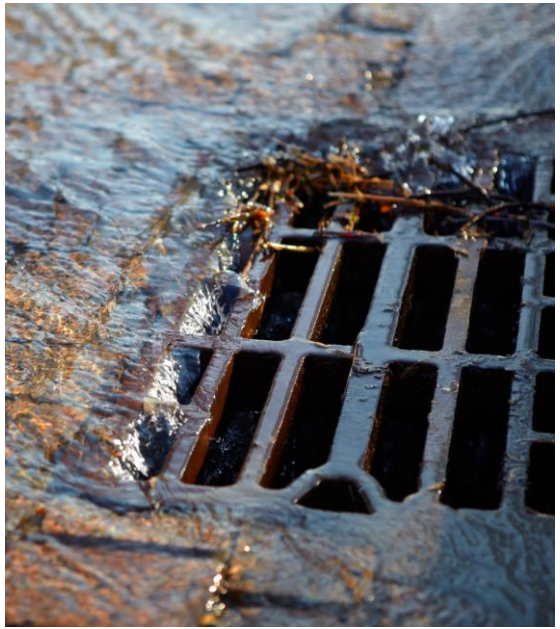



DATA INFORMS DECISION

ARGONNE EXPERTS FORM MULTIDISCIPLINARY TEAMS

Answer Impact-Specific Questions, Provide Actionable Information



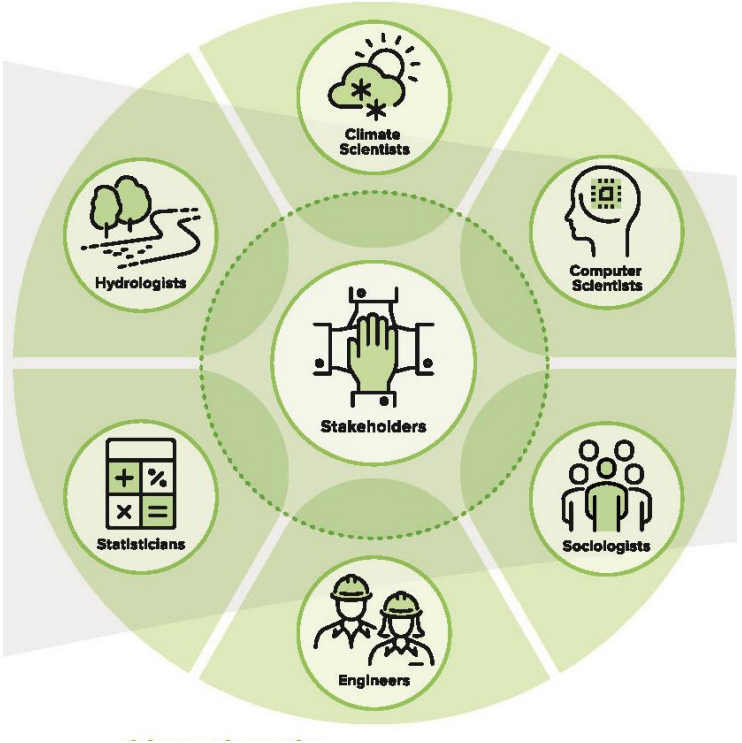
ARGONNE EXPERTS FORM MULTIDISCIPLINARY TEAMS

Climate Science Enabling Decisionmaking

STATISTICIANS
determine extreme event intensities

ENVIRONMENTAL MODELERS
determine location-/region-specific impacts

ENGINEERS
determine critical asset/system thresholds and impacts



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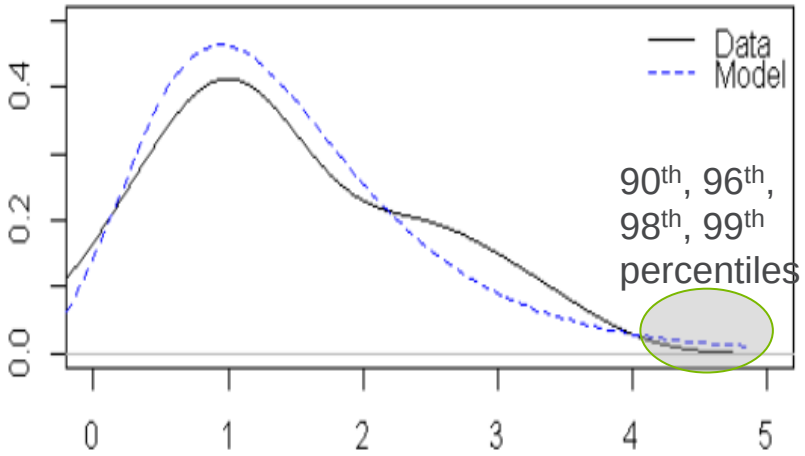
STATISTICAL ANALYSIS PROJECTS EXTREMES AND FLOOD RISKS

DYNAMIC DOWNSCALE PRECIPITATION DATA (12km RUNS) INFORMS SURFACE HYDROLOGY MODEL AT 200m RESOLUTION FOR ALL OF SOUTHEASTERN USA

- 10- year simulations for present-day and mid-century
- Ensemble of downscaled simulations
- GEV fitting to develop the PDF of maximum water depths for each 200m grid cell



$$\xi \neq 0, G(x) = \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-1/\xi}\right\}$$

$$\xi = 0, G(x) = \exp\left\{-\exp\left(-\frac{x-\mu}{\sigma}\right)\right\}$$

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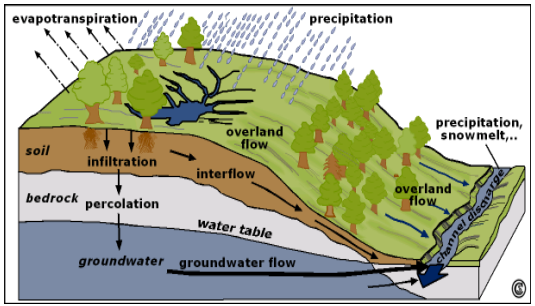
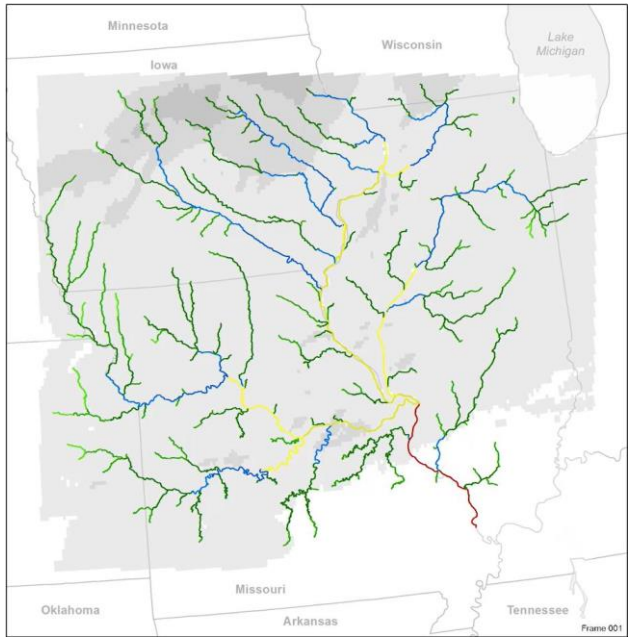
WRF-HYDRO: TOOL FOR ANALYZING TOPOGRAPHY AND PRECIPITATION RUNOFF

- **Serves national hydrological forecast**
- **Argonne is first to:**
  - Run WRF-Hydro on high-performance computers
  - Apply WRF-Hydro over a large domain





RIVER DISCHARGE

SURFACE FLOODING

FLASH FLOODING

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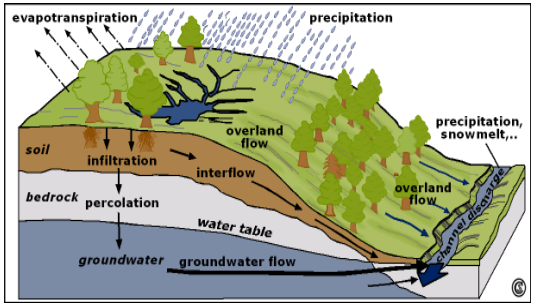

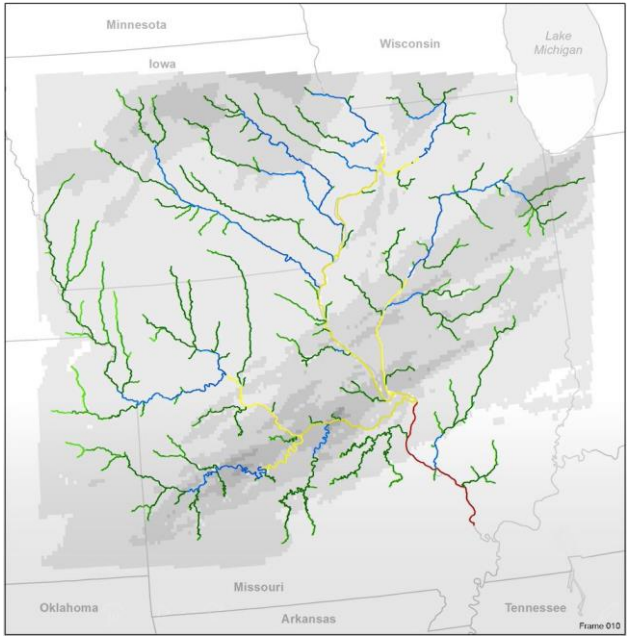

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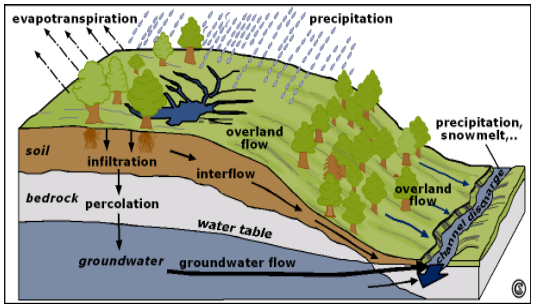

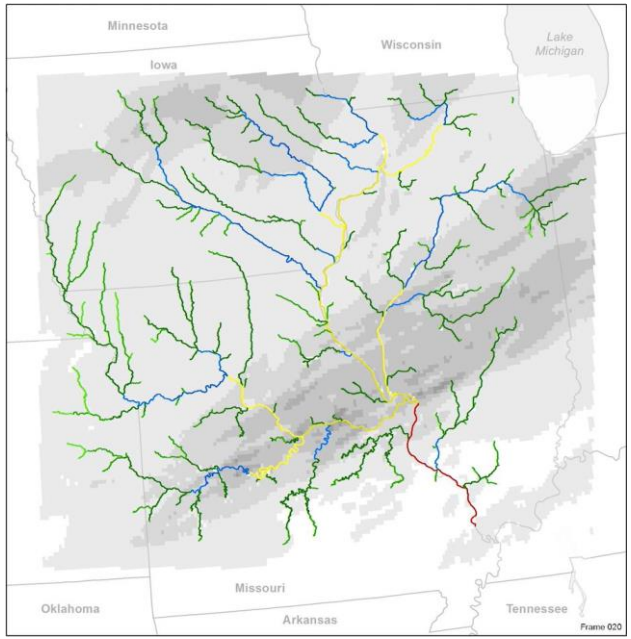

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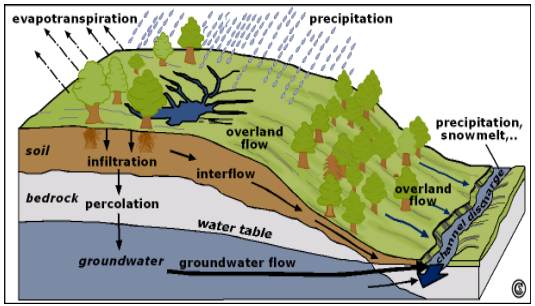

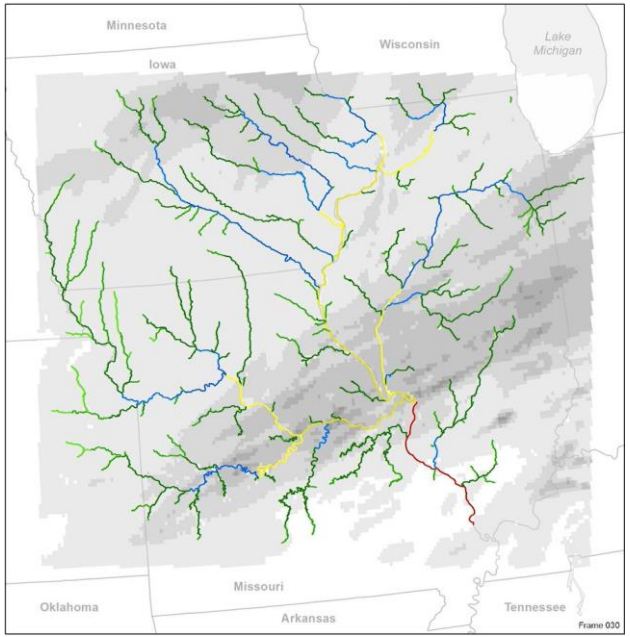

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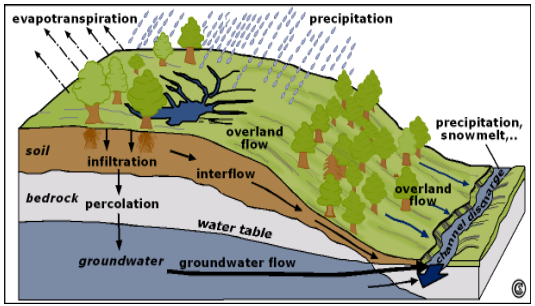

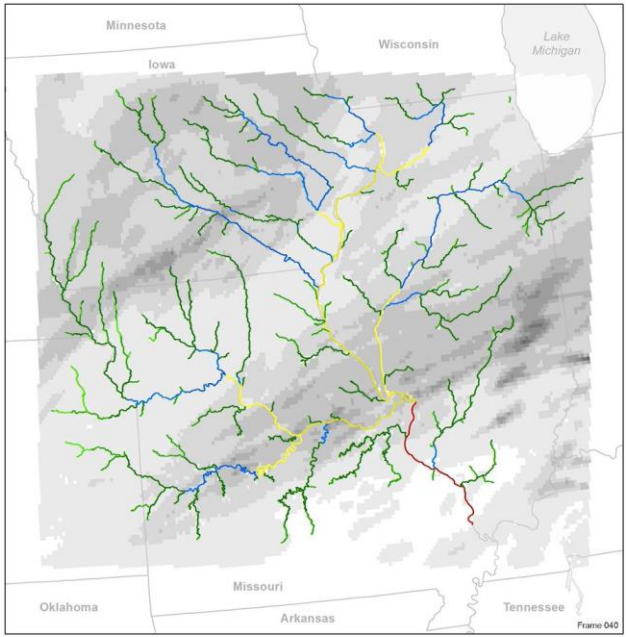

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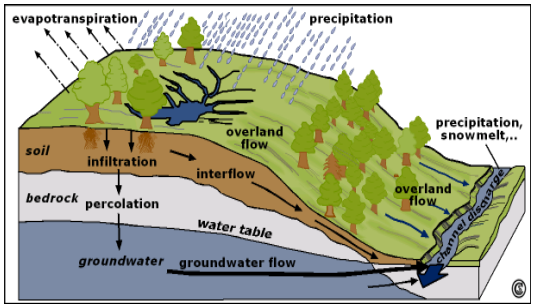

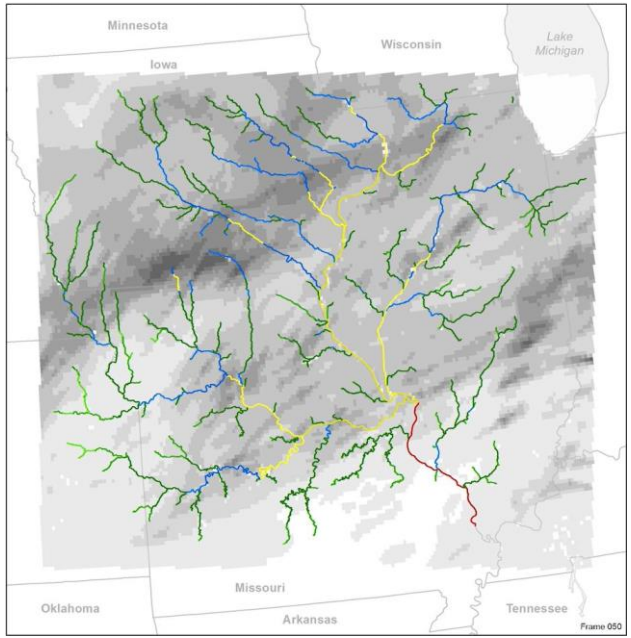

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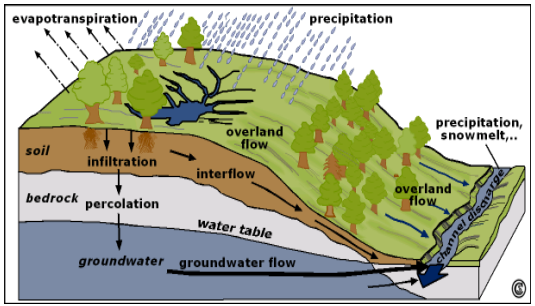

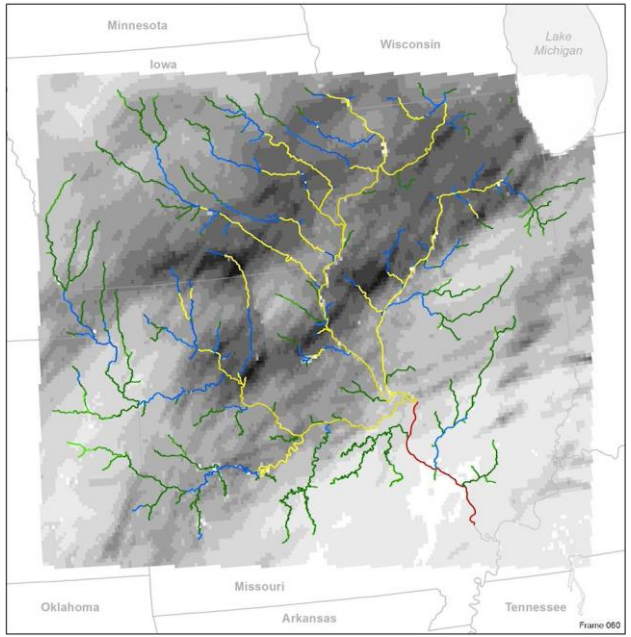

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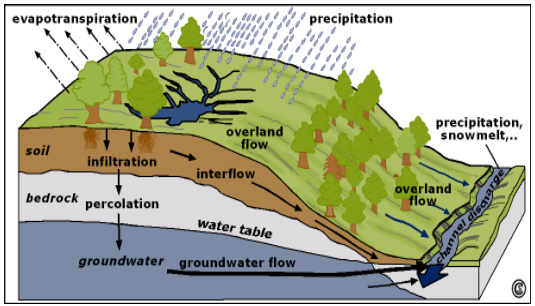

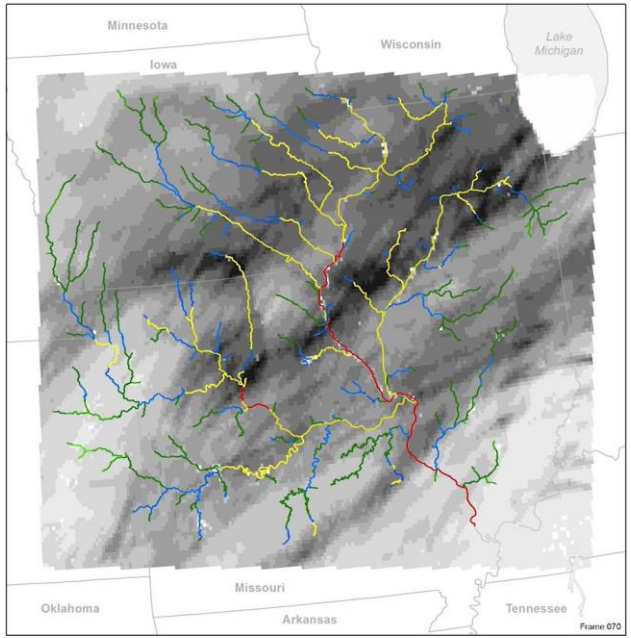

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SURFACE FLOODING

FLASH FLOODING

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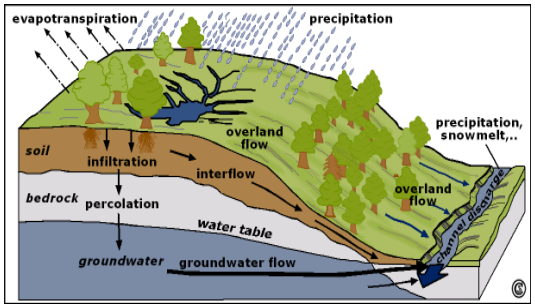
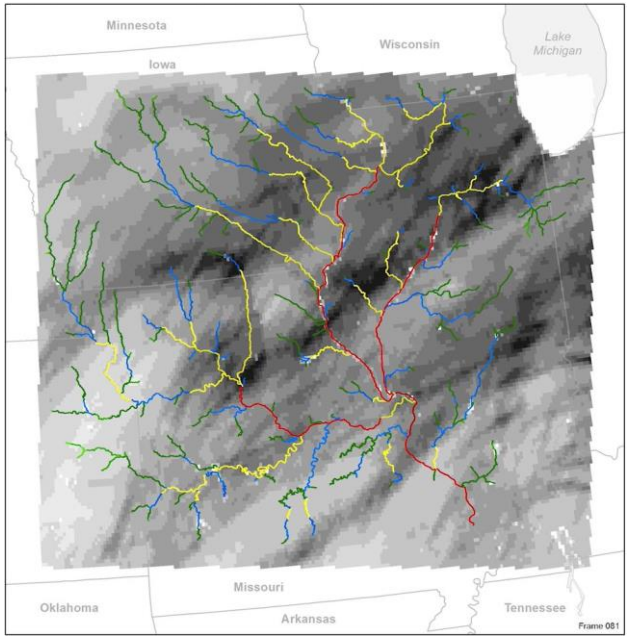
WRF-HYDRO: TOOL FOR ANALYZING TOPOGRAPHY AND PRECIPITATION RUNOFF

- **Serves national hydrological forecast**
- **Argonne is first to:**
  - Run WRF-Hydro on high-performance computers
  - Apply WRF-Hydro over a large domain





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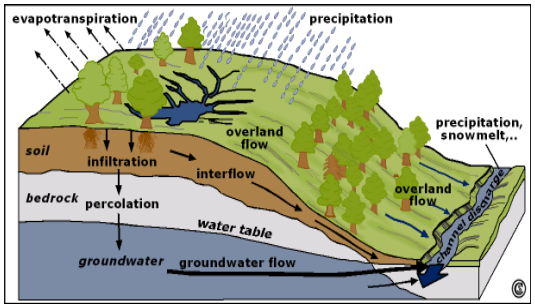

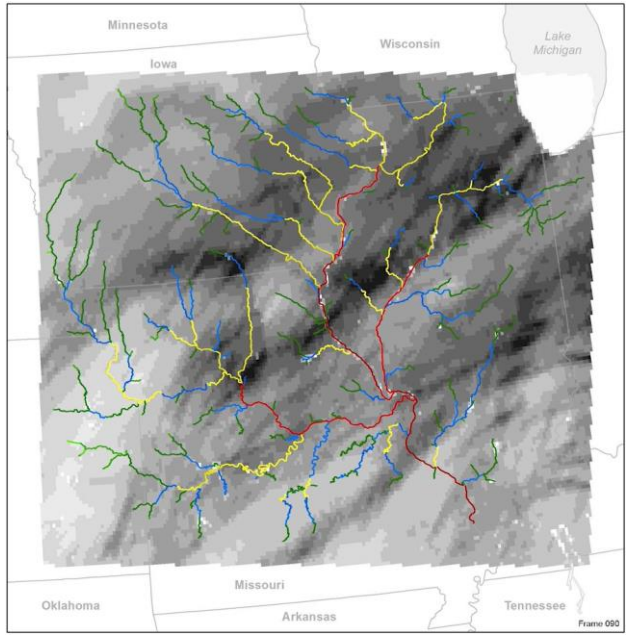

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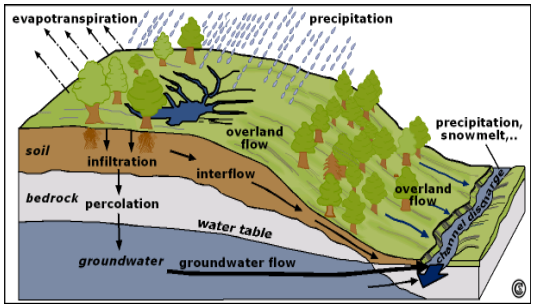

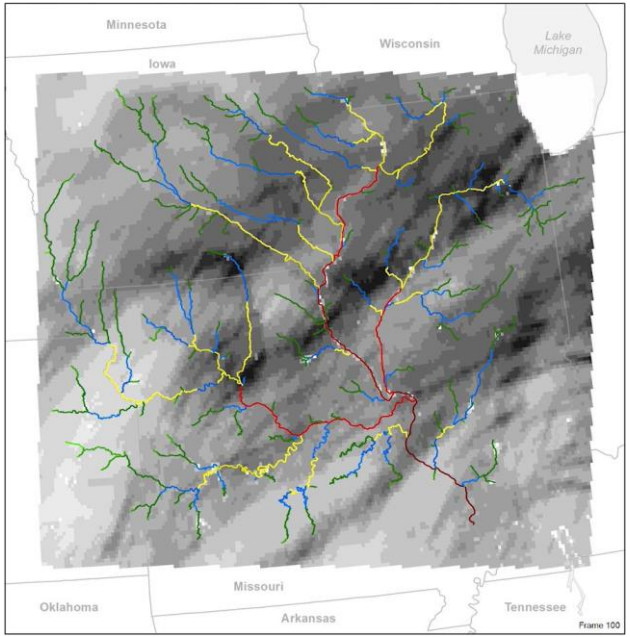

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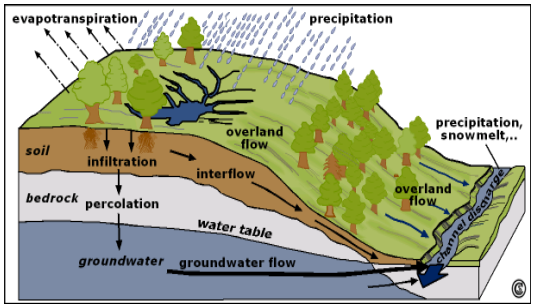

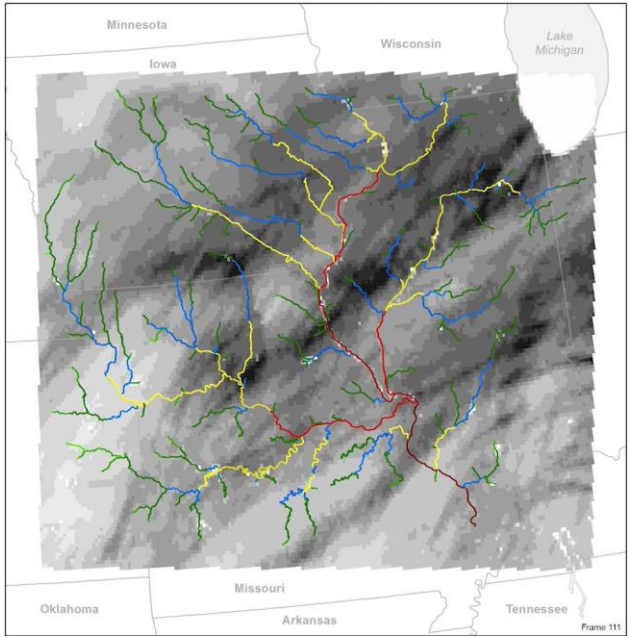

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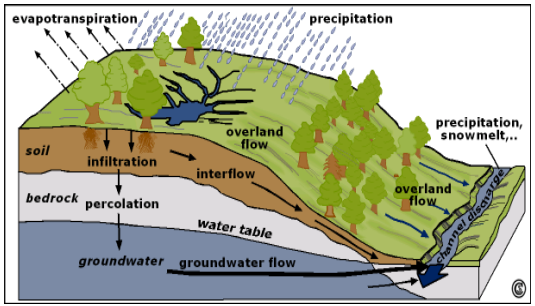

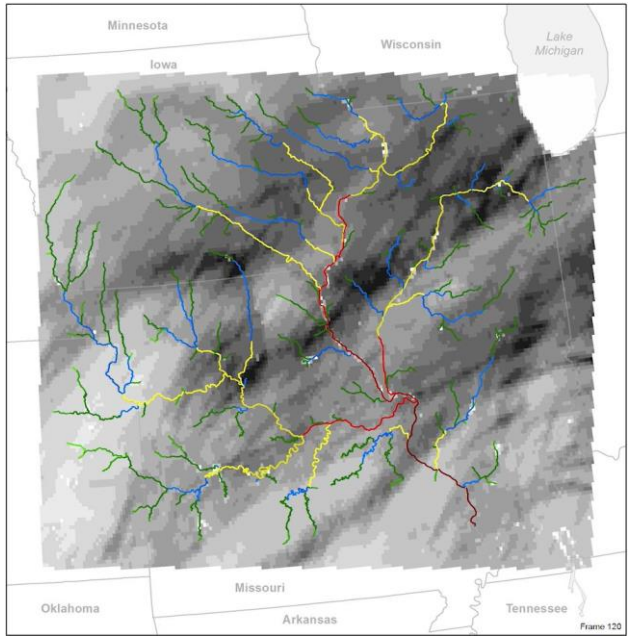

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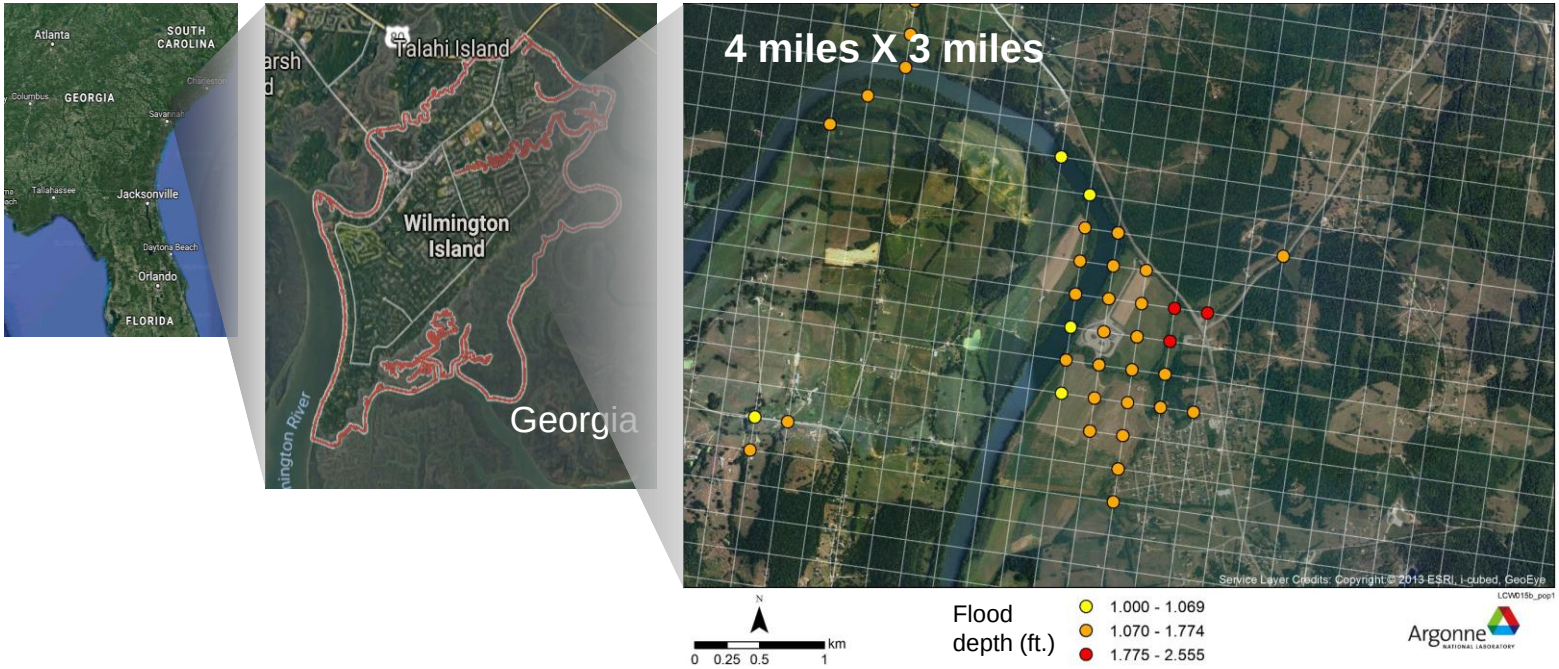
MODEL ALLOWS FOR NEIGHBORHOOD SCALE PROJECTIONS

AT&T Partnership



Time interval

- Water depth: 2hr, 3hr or 6hr
- Streamflow: 2hr

Spatial resolution: 200 meters

Number of grid cells: 5180 x 6980 = 36.15 millions

INFORMING DECISIONS

AT&T Partnership

PROJECTING COMBINED COASTAL AND INLAND FLOOD RISKS

- Future hurricane coastal flooding
  - Winds, wave and storm surge at 50m-90m resolution
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  - Capital planning/investment
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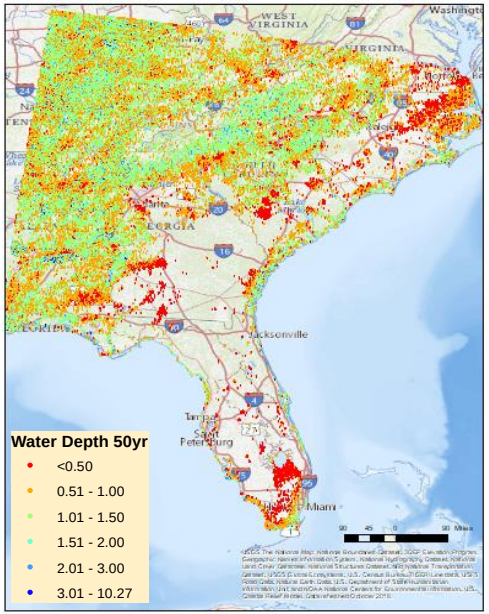

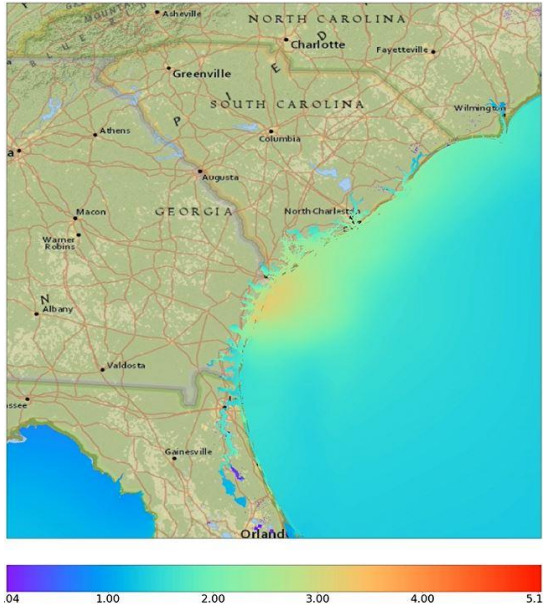

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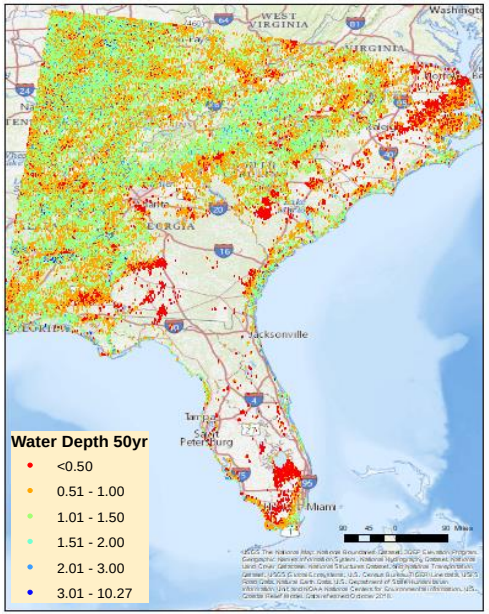

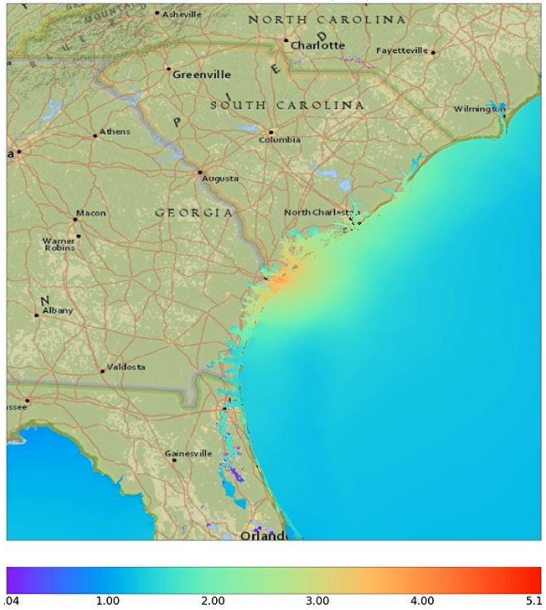

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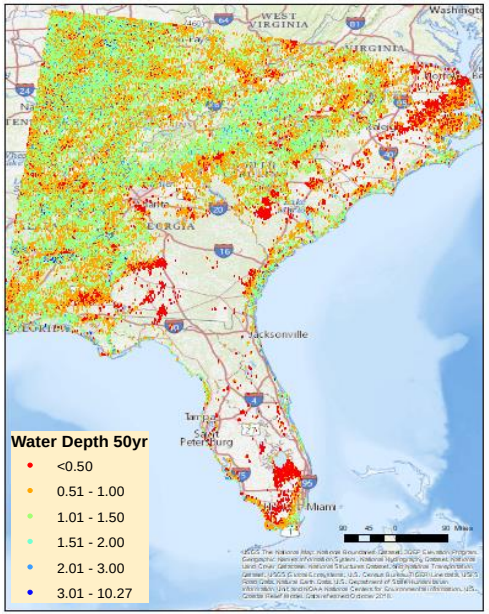

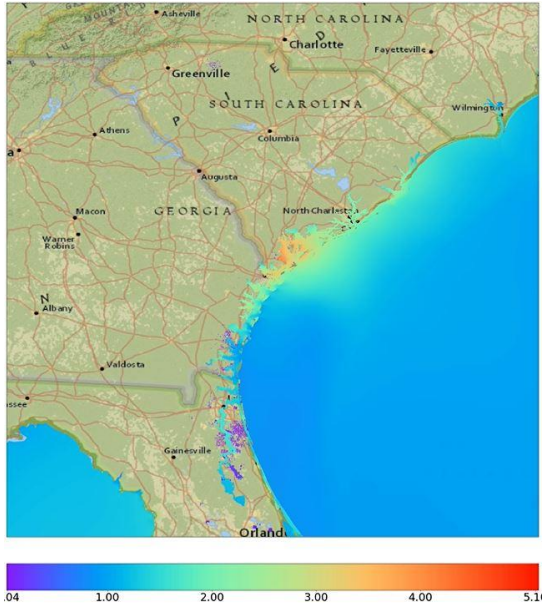

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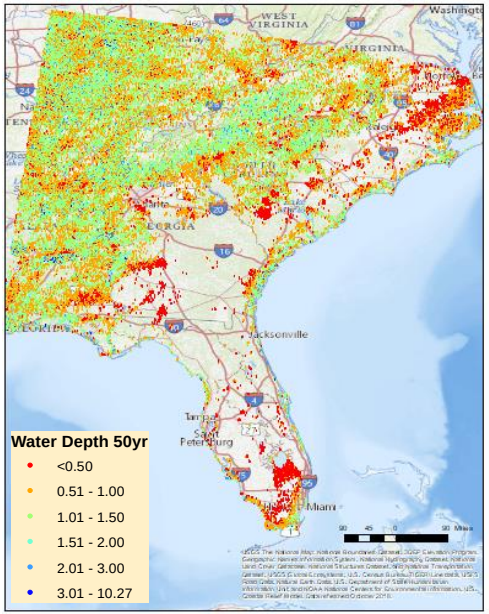

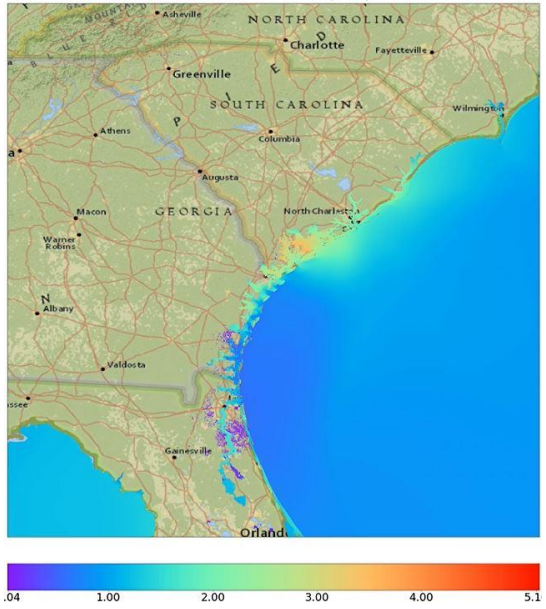

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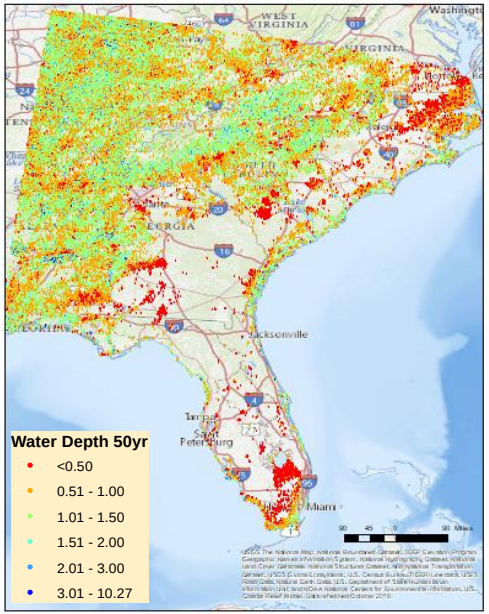

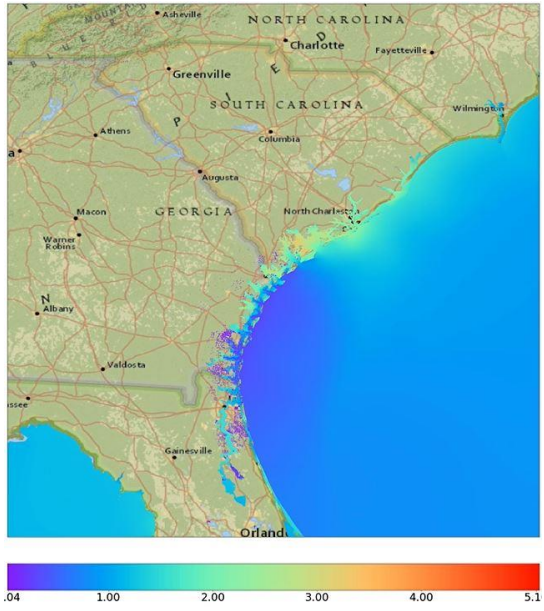

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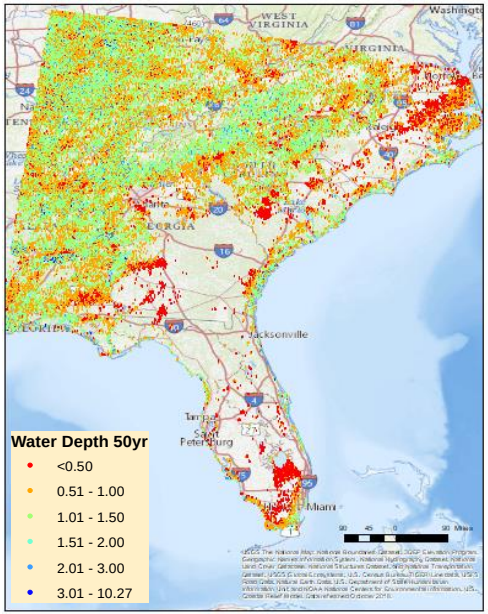

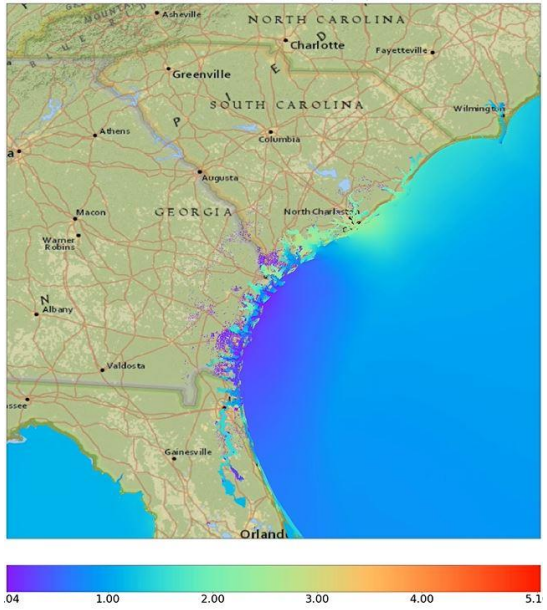

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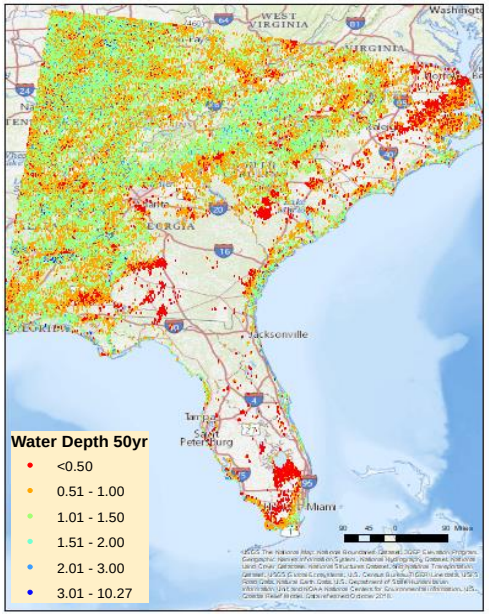

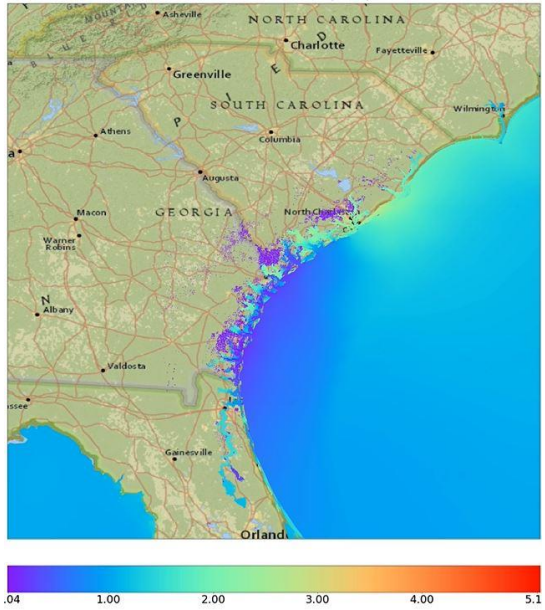

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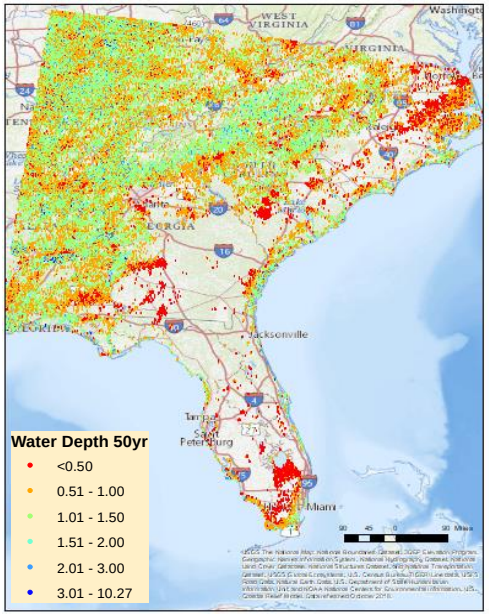

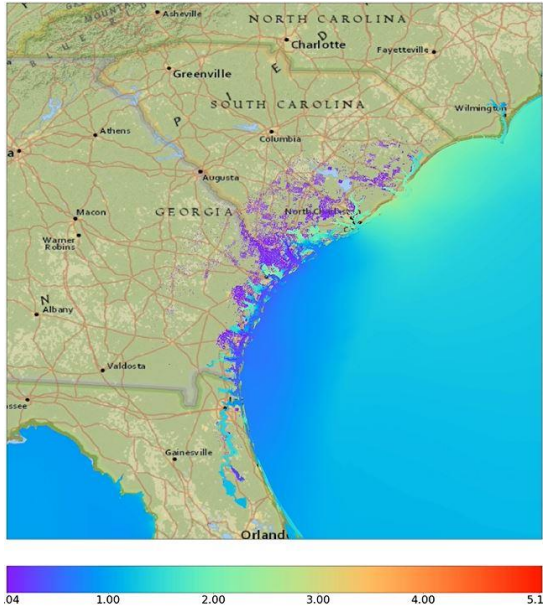

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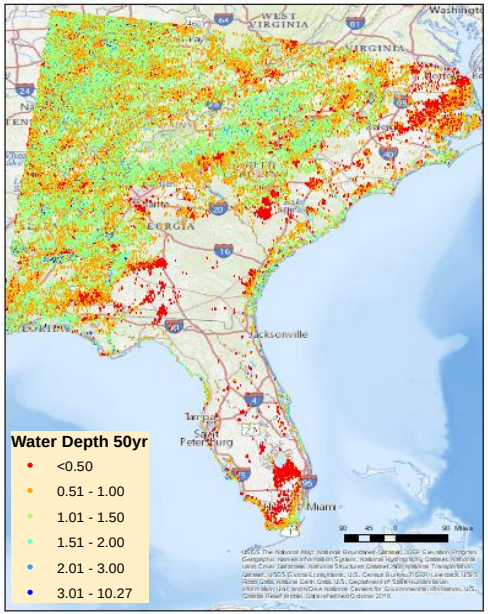

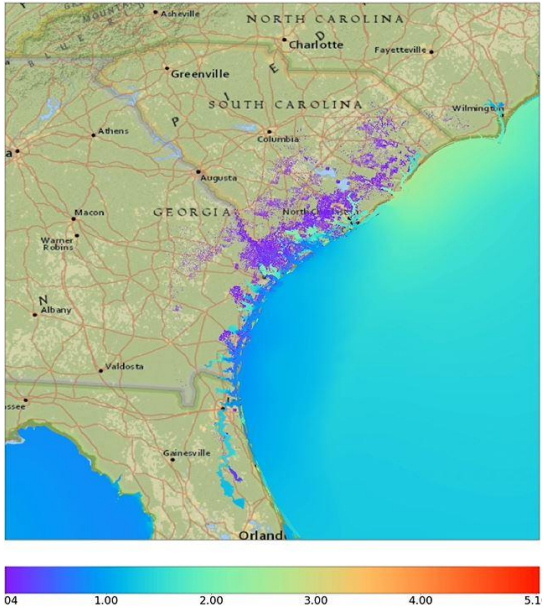

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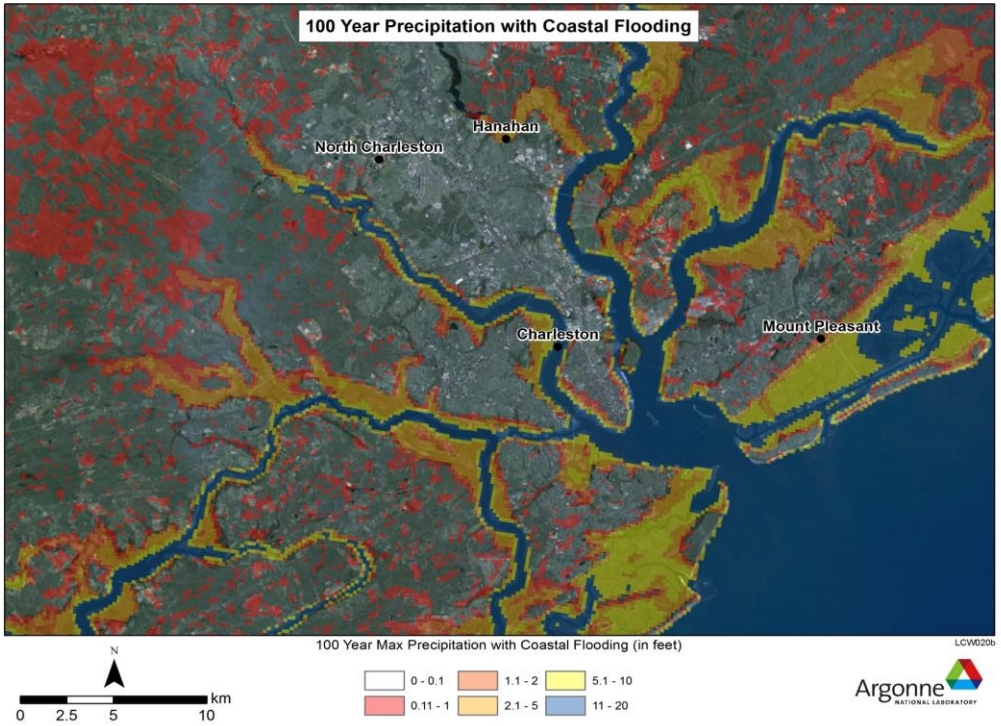

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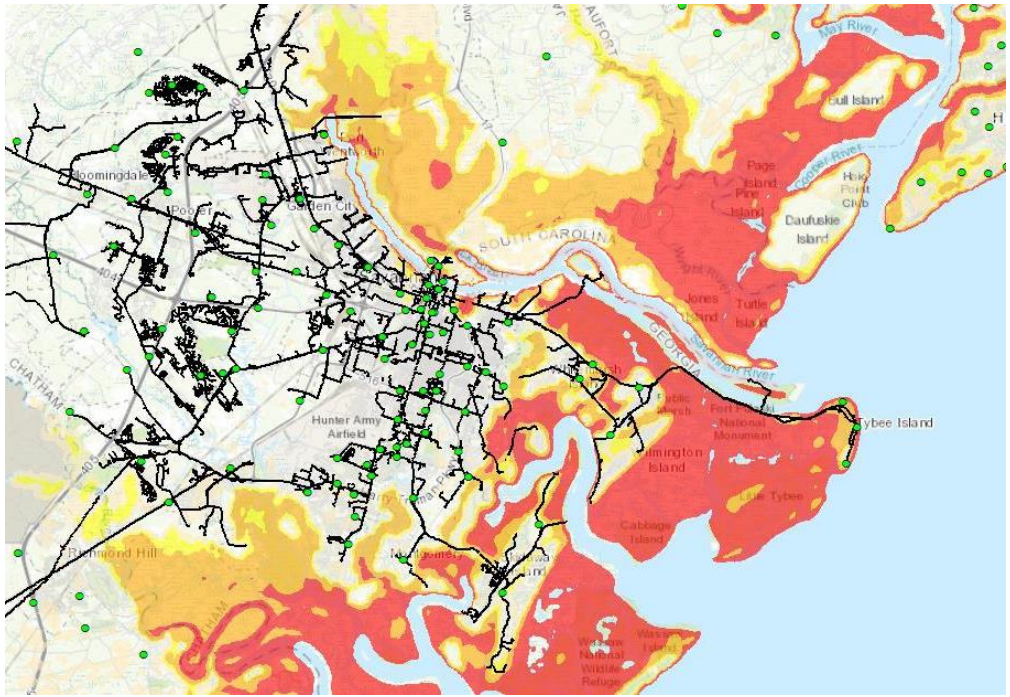
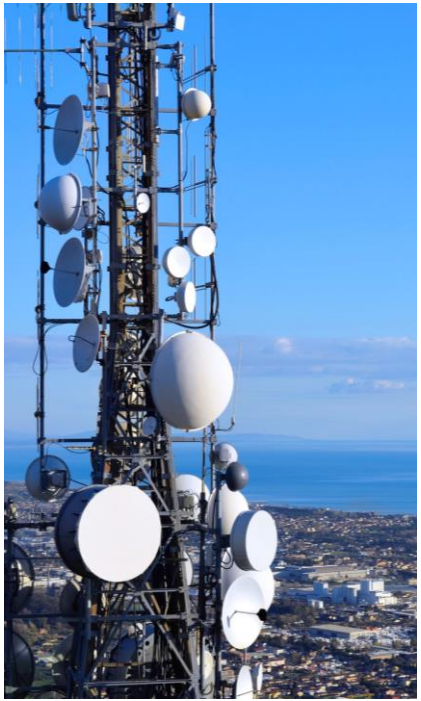


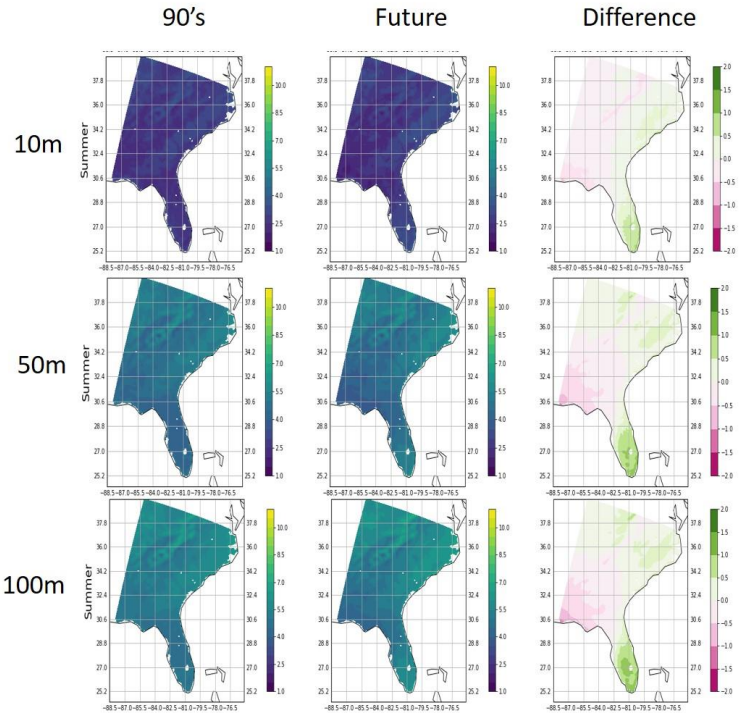
INFORMING DECISIONS

AT&T Partnership

PROJECTING FUTURE WIND INTENSITIES AND EXTREMES

- Statistical modeling projects changes in wind intensities across the Southeast
- Incorporated high-resolution local topographical datasets
- Projected wind intensities at 10, 50 and 100 meters above the ground
- Changes in 50-year wind intensities inform structural design for lateral wind loading





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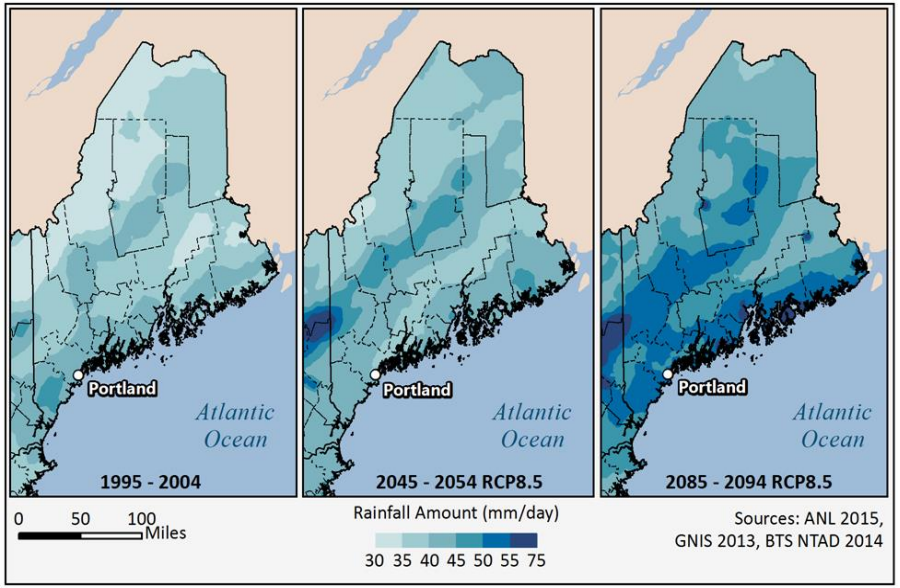
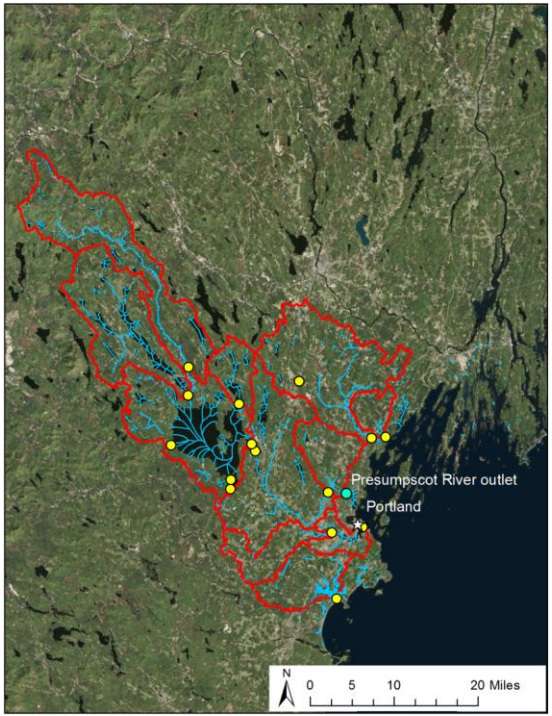
INFORMING DECISIONS

Maine Critical Infrastructure

Stormwater flood risks to urban stormwater and transportation systems





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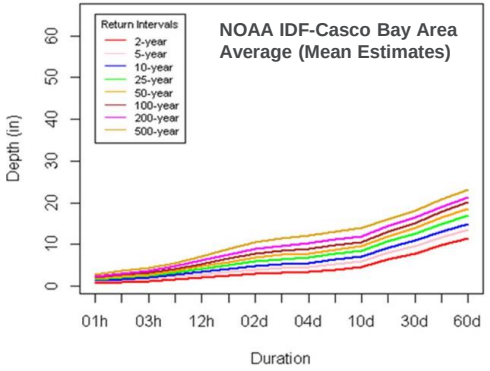
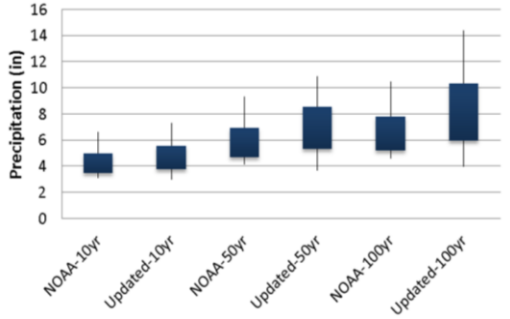
INFORMING DECISIONS

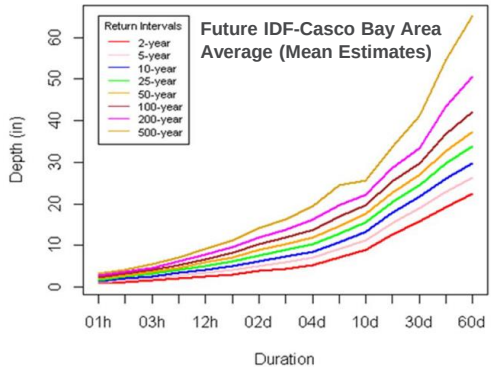
Maine Critical Infrastructure

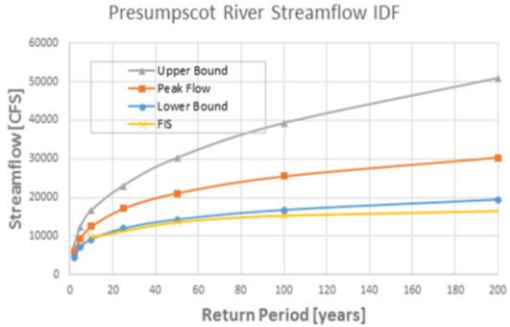
STORMWATER FLOOD RISKS TO TRANSPORTATION STORMWATER SYSTEMS

- Modeled regional watersheds using USACE's HEC-HMS software
- Model future stream flows using precipitation from 12km climate model projections
- Compared projections with NOAA historical precipitation intensities
- Developed Intensity-Duration-Frequency (IDF) curves, updated for future precipitation









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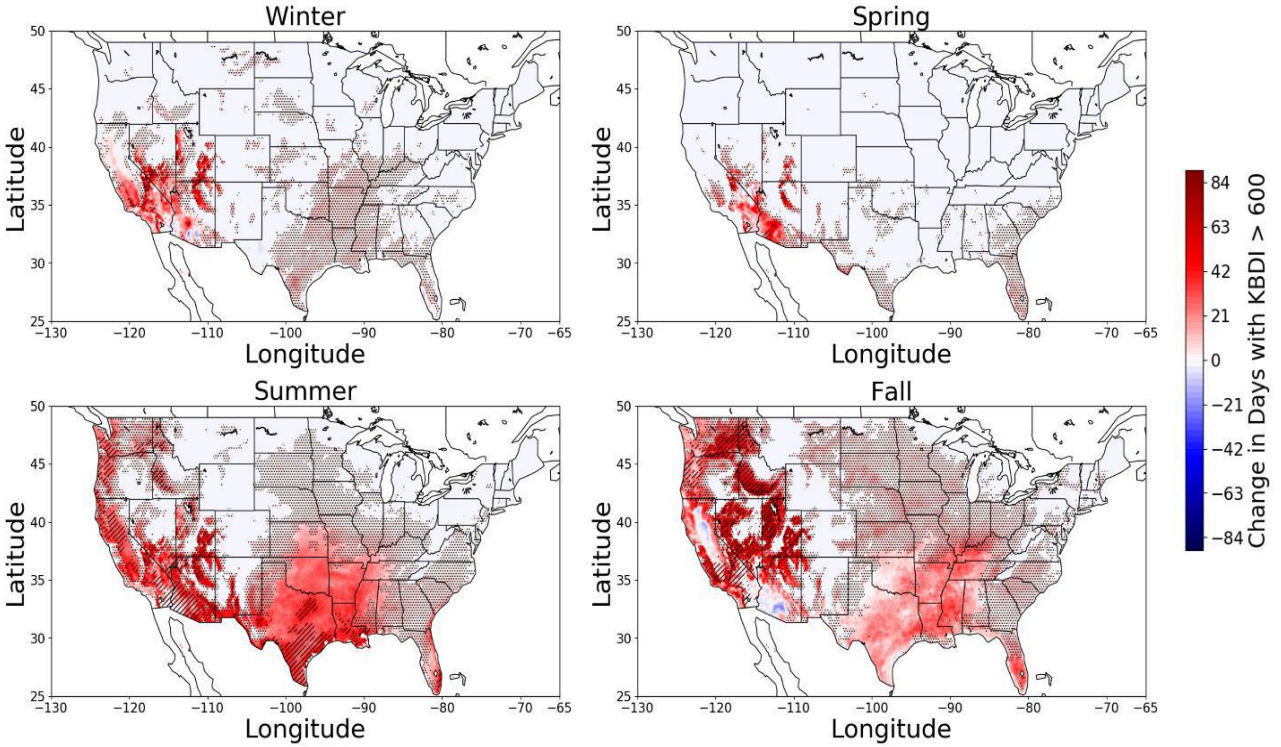
CLIMATE MODELS INFORM FUTURE WILDFIRE RISKS NATIONWIDE

DYNAMICALLY-DOWNSCALED DROUGHT INDEXES FOR FUTUREWILDFIRE RISKS

- Keech-Byram Drought Index (KBDI) developed by USDA Forest Service
- KBDI >600 correlates with large burned area and intense fire activity
- Projected to broaden by nearly 60 times in the southern CONUS
- Figure shows change in the number of days with KBDI > 600 from the historical period to late 21st century



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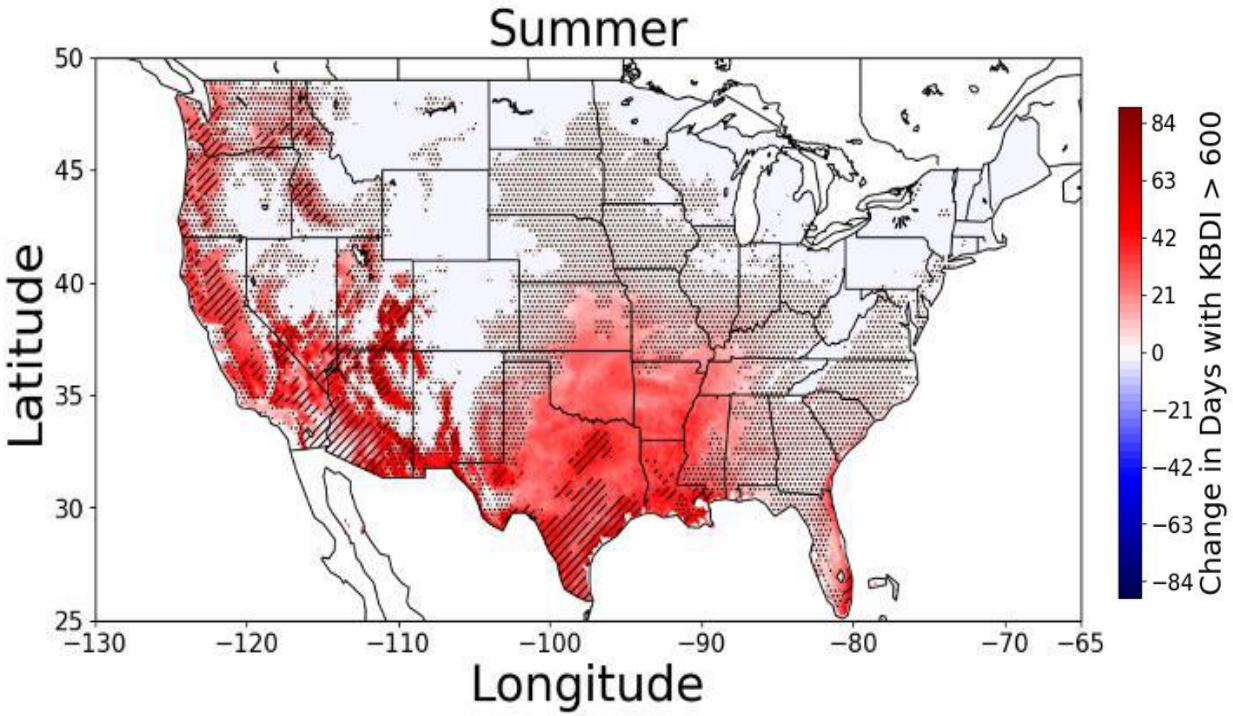
- Figure shows change in the number of days with KBDI > 600 from the historical period to late 21st century



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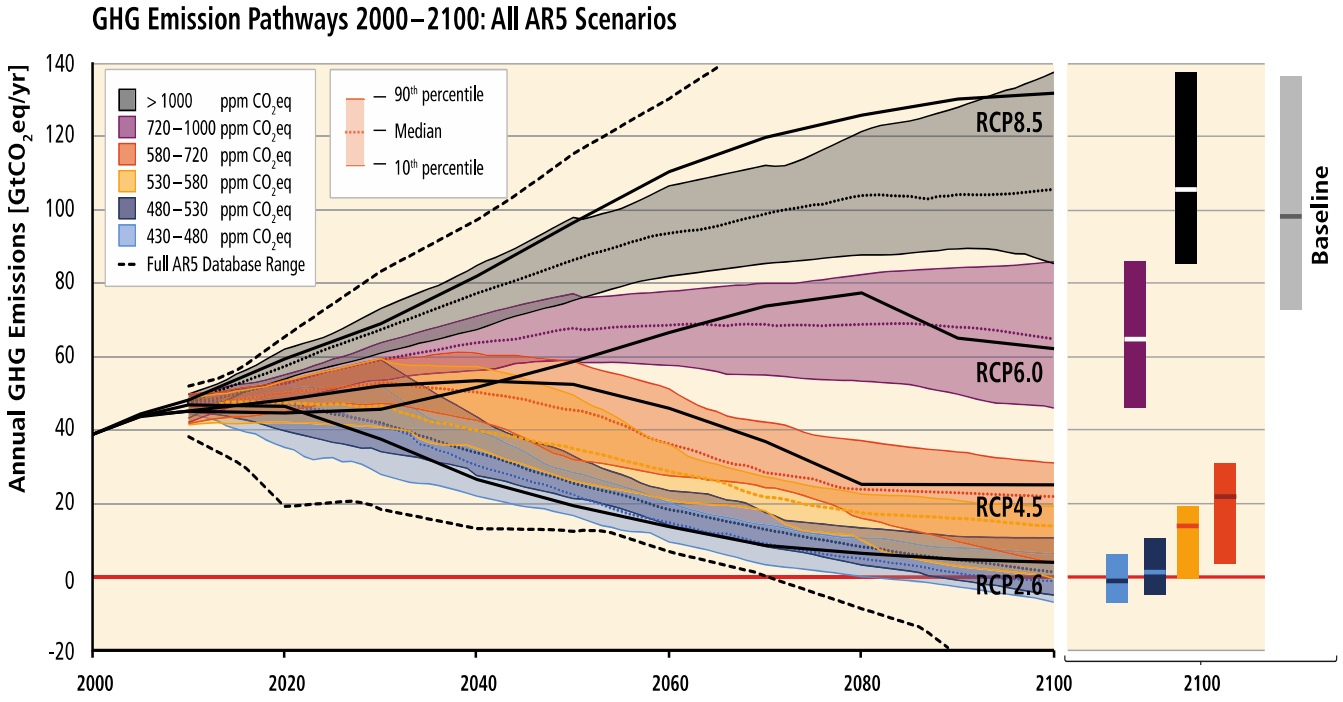
UNCERTAINTY, RESILIENCE, AND DECISIONS

THE BIGGEST UNCERTAINTY IS THAT WE DON'T KNOW WHAT PEOPLE WILL DO



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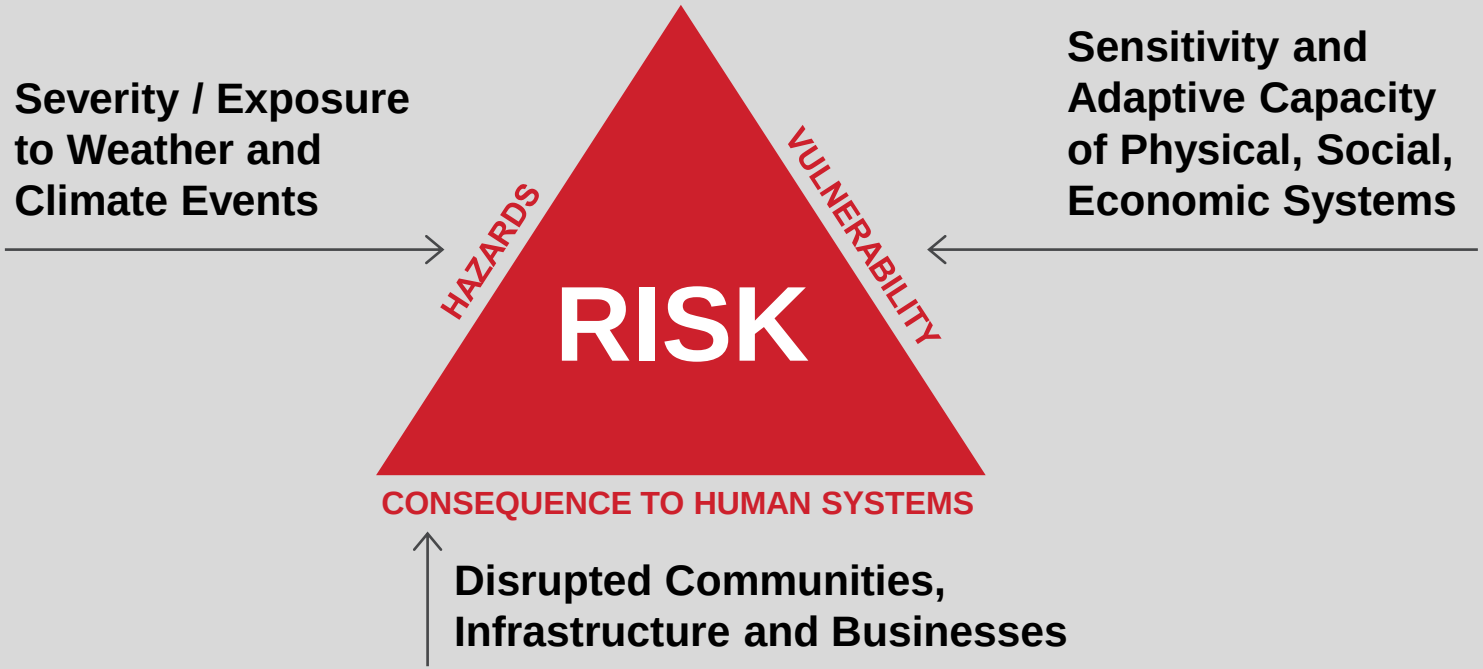
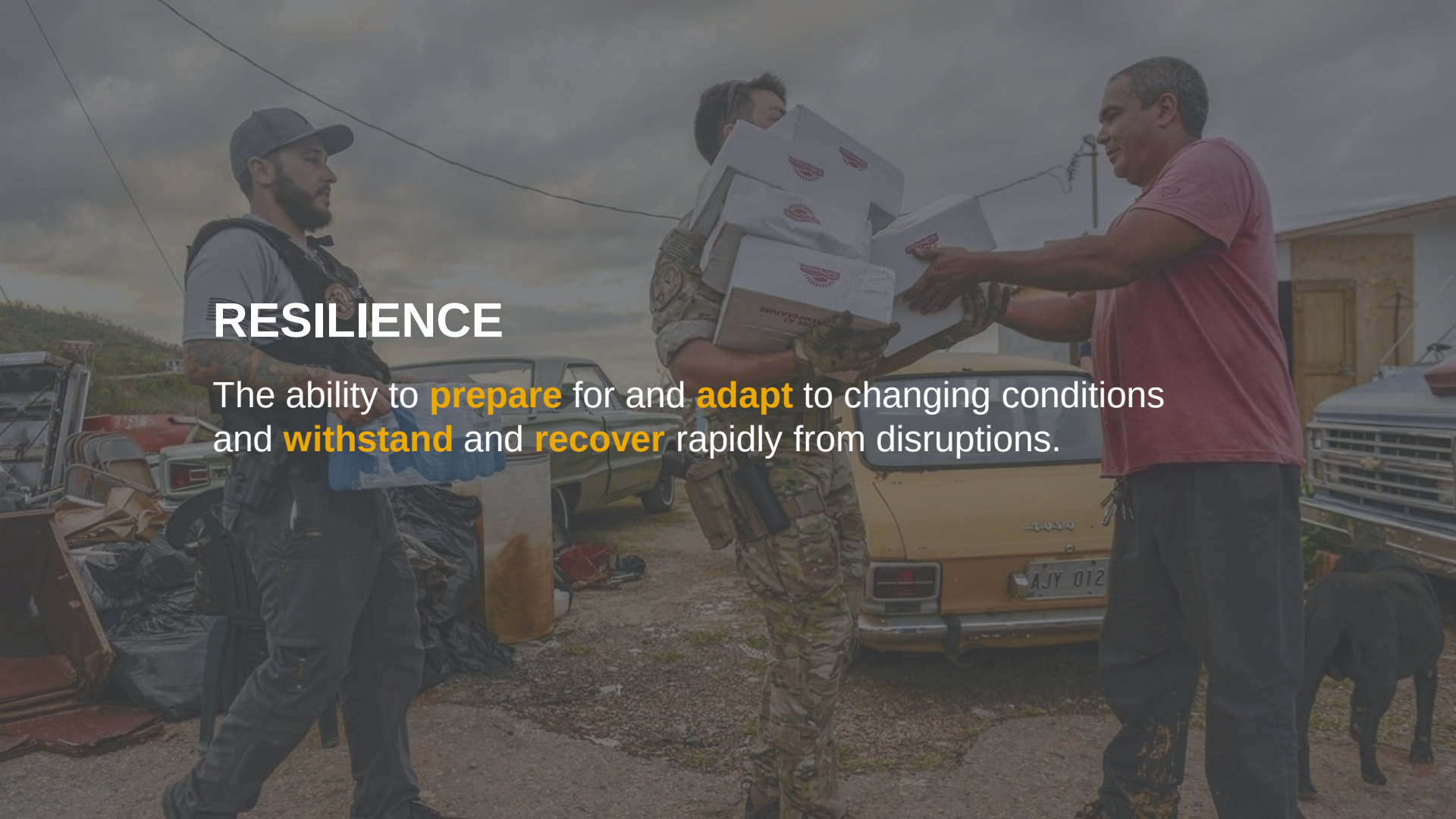

Severity / Exposure to Weather and Climate Events
HAZARDS
RISK
VULNERABILITY
Sensitivity and Adaptive Capacity of Physical, Social, Economic Systems
CONSEQUENCE TO HUMAN SYSTEMS
Disrupted Communities, Infrastructure and Businesses



RESILIENCE

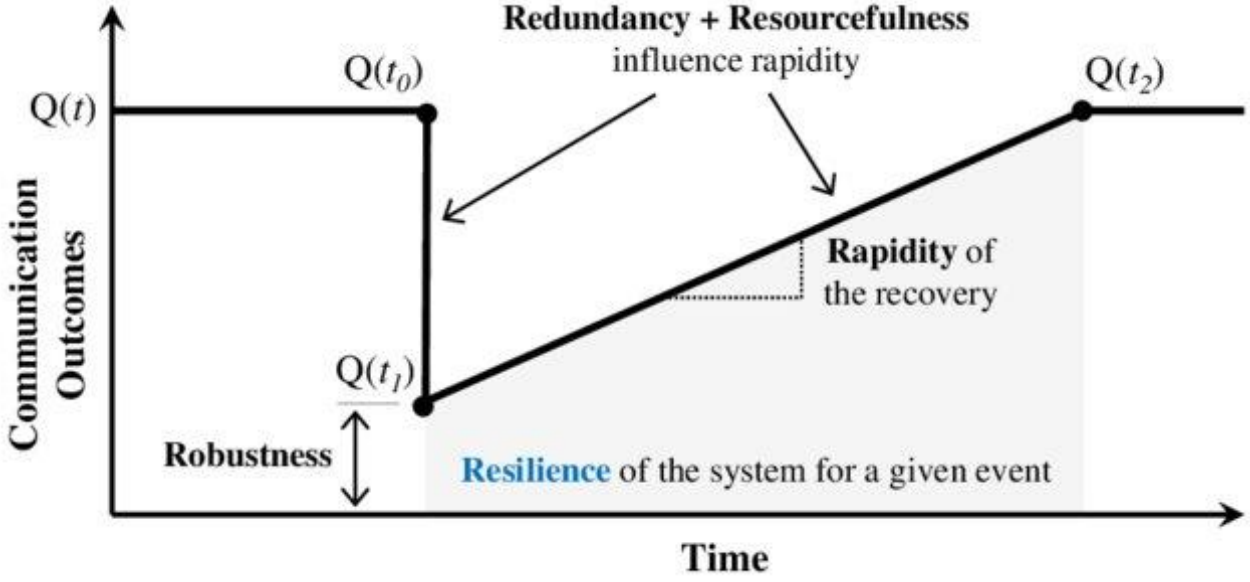
The ability to **prepare** for and **adapt** to changing conditions and **withstand** and **recover** rapidly from disruptions.

CONCEPTUALIZING DISASTER RESILIENCE

Resilience Triangles / Curves

Resilience Elements

1. Prepare
2. Adapt
3. Withstand
4. Recover



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CONCEPTUALIZING DISASTER RESILIENCE

Resilience Triangles / Curves

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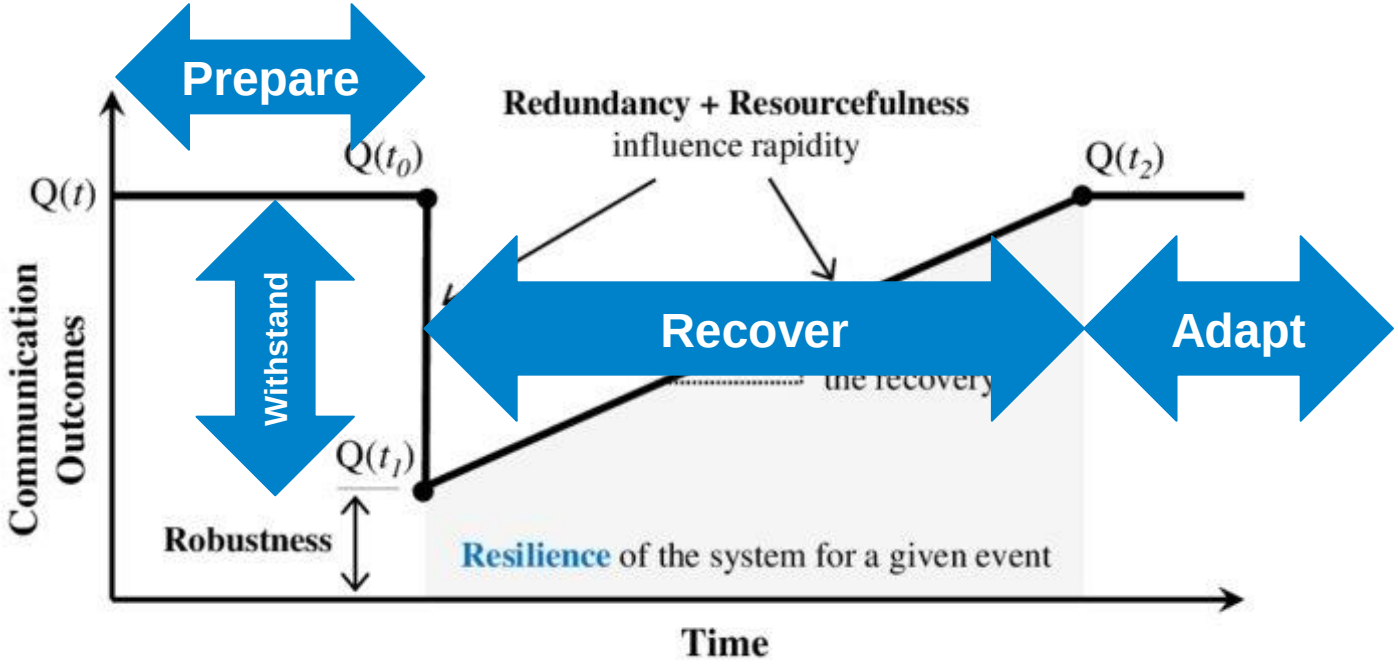

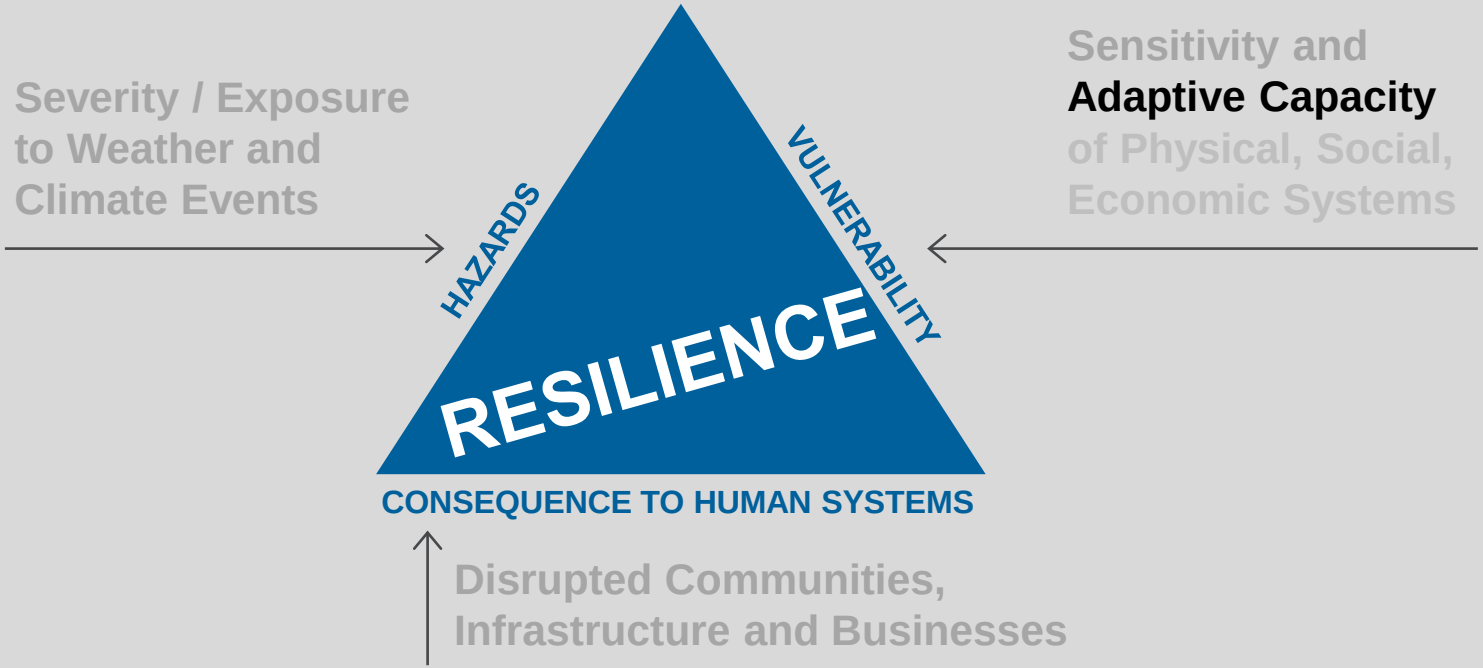
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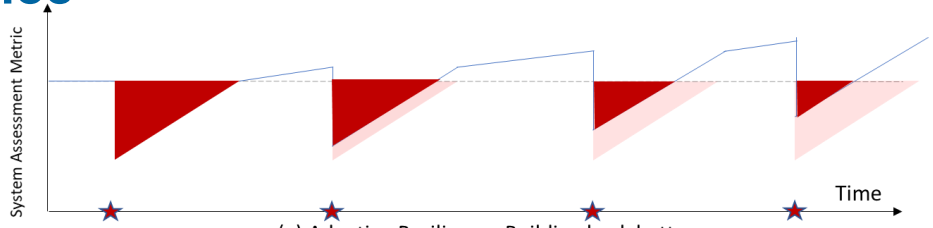
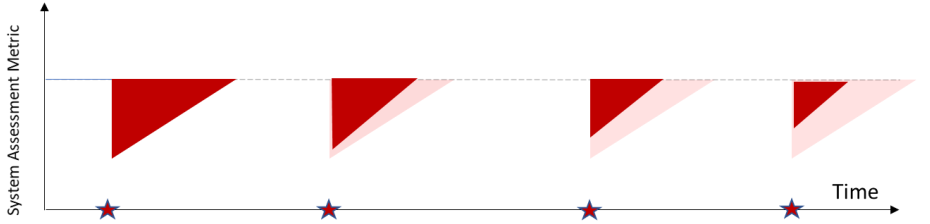
CONCEPTUALIZING DISASTER RESILIENCE

Adaptive Resilience

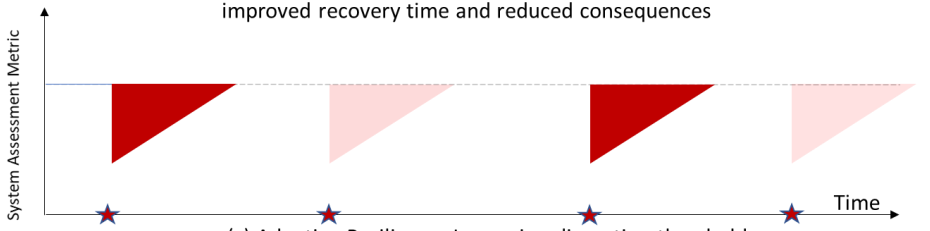
- **Build Back Better**
- **Improve Response & Recovery**
- **Improve Robustness to Disruption**



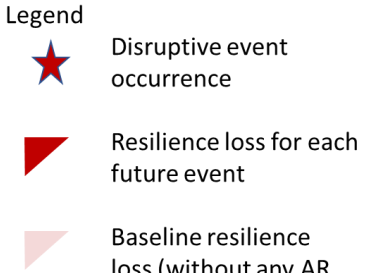
(a) Adaptive Resilience: Building back better



(b) Adaptive Resilience: Continuous reduction of resilience triangle-improved recovery time and reduced consequences



(c) Adaptive Resilience: Improving disruption threshold



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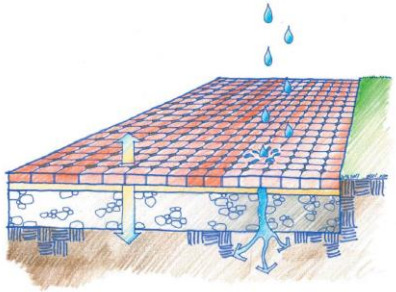
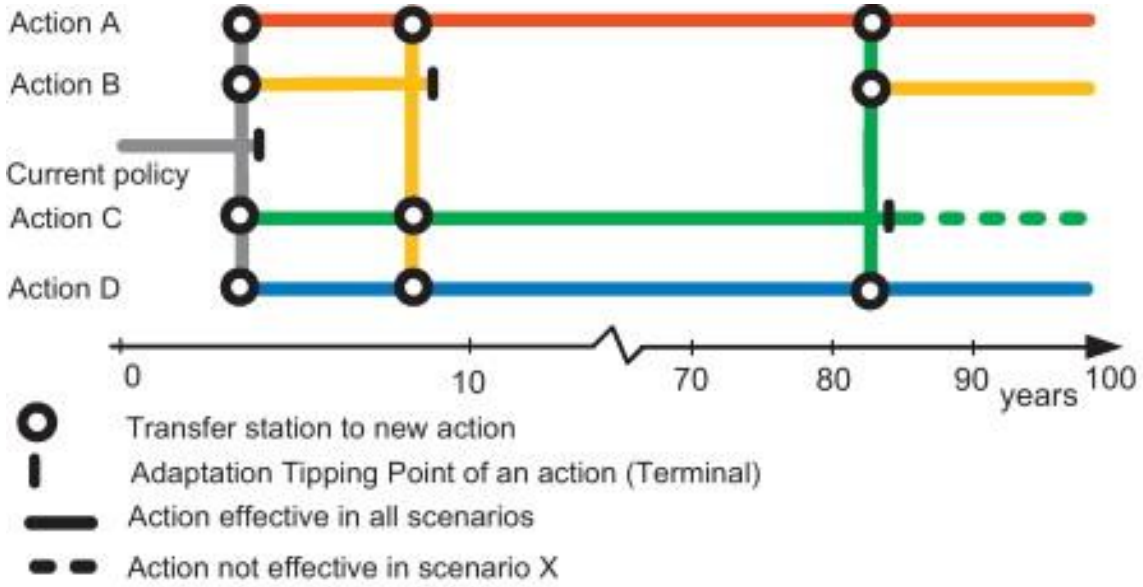
ADAPTIVE CAPACITY

Green Infrastructure



ADAPTIVE CAPACITY

Real Options and Dynamic Adaptive Planning (Policy Pathways)



Adaptation Pathways Map

	Path actions	Relative Costs	Target effects	Side effects
1		+++	+	0
2		+++++	0	0
3		+++	0	0
4		+++	0	0
5		0	0	-
6		++++	0	-
7		+++	0	-
8		+	+	- - -
9		++	+	- - -

Scorecard pathways

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THANK YOU.

Tom Wall
twall@anl.gov


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