U.S. GREEN BUILDING COUNCIL

G325

Climate Resilience Primer Course

USGBCNYU_CRPC

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Learning Objectives

At the end of the this course, participants will be able to:

1. Explain how climate impacts on buildings and its occupants, users and any others will become increasingly severe as the climate itself becomes more severe.
2. Identify and prioritize climate adaptation strategies in project planning and design to meet the most pressing needs of a particular building in a particular place at a particular time.
3. Explain the differences between mitigation and adaptation design strategies for project planning and design.
4. Understand regulations, codes, and standards as both a tool and a barrier for climate adaptation.

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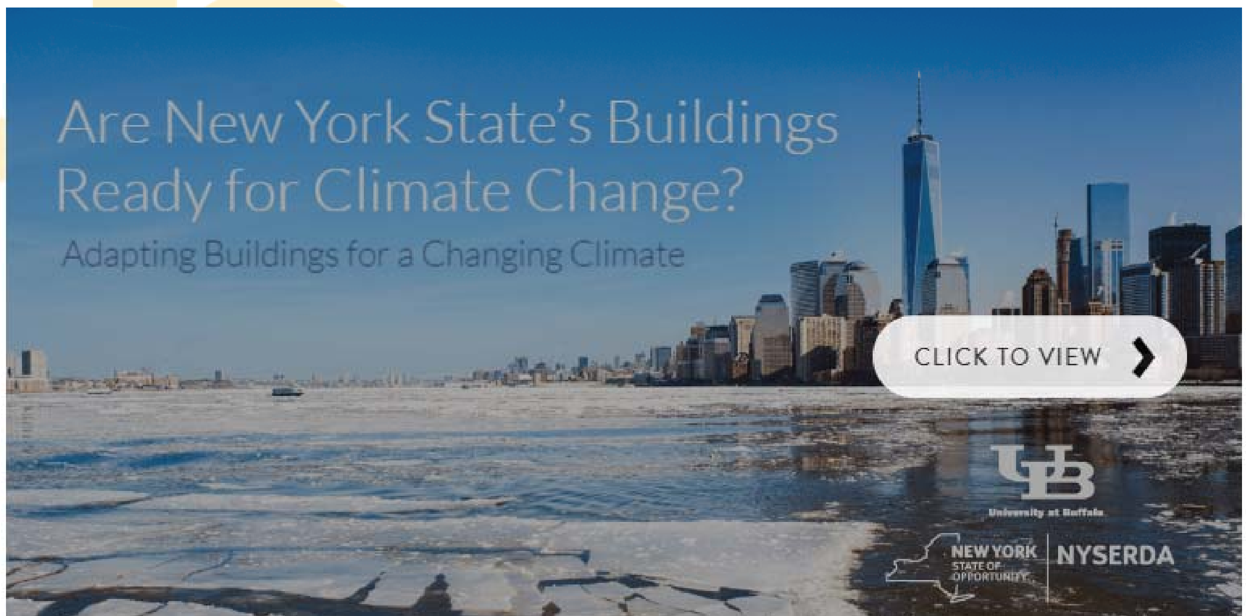
Adapting Buildings for a Changing Climate



New York's climate is changing. Are your buildings prepared?

Research

- Our Approach
- Centers and Labs
- Initiatives
  - The UB Affordable Housing Initiative
  - Adapting Buildings for a Changing Climate
  - See It Through Buffalo
  - University Heights Initiative
- Insights

Related Links

- Graduate Research in Architecture
- Graduate Research in Urban Planning

ap.buffalo.edu/adapting-buildings

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Introduction

- Climate change is driven by the increase in levels of greenhouse gases, concentrations of which are now one-third higher than in pre-industrial times.

- While reducing greenhouse gases is critical, this course discusses the impacts of climate change on buildings, not the impact of buildings on climate change.

- This is because buildings need to work successfully in both the current and future climate, and there is a pressing need to address environmental concerns other than climate change as well.

A Changing Climate Impacts Buildings

- Climate impacts on buildings will become increasingly severe as the climate warms. Because climate risks to buildings are not the same in all locations, they must be addressed on a regional basis.

- Climate change creates challenging impacts to building stocks, through extreme temperatures, increased storm severity and frequency, and changing precipitation patterns.

Buildings and Change

- The climate is not currently projected to stabilize at a new normal within the next century but rather is expected to continue to shift over the coming decades. There is no “new normal.”
- This suggests that an iterative process to climate adaptation is helpful; making communities resilient is a long-term endeavor as buildings are renovated or built to new standards that take into account climate.
- 100% resilience is an impossible goal for buildings.
- Prioritizing adaptation strategies is important to meet the most pressing needs of a particular building in a particular place at a particular time; there are no universal prescriptions to make buildings resilient to climate change.

Key Terms

- **ADAPTATION**: The process of preparing for an intensifying climate by making adjustments for actual or expected effects. Adaptation seeks to moderate harm, exploit beneficial opportunities, and cope with the consequences of climate change.

- **HAZARD**: A climate events that cause damage to a building.

- **IMPACTS**: The potential effects a change in climate has or could have on buildings or occupants.

- **MITIGATION**: Reducing the magnitude of climate change.

Key Terms

- **RESILIENCE**: The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

- **RISK**: A product of the probability of a climate hazard occurring, the likelihood of impacts from that hazard, and the magnitude of consequences if that impact occurs.

- **VULNERABILITY**: The degree to which buildings, occupants, and related social systems are susceptible to and unable to cope with the adverse impacts of climate change.

Mitigation vs. Adaptation

- **MITIGATION** has been described as avoiding the unmanageable and **ADAPTATION** as managing the unavoidable.

- Greenhouse gas mitigation is reducing greenhouse gas emissions to help slow global warming, such as through sustainable building design.

- Adaptation is preparing buildings for intensifying climate conditions to improve building performance and reduce risk to expected hazards.

Regulations: Codes and Standards

- Many energy and climate-related design and operational decisions for buildings are governed by building and energy codes, which set prescriptive or performance-based requirements grounded in a location's historical climate data.

- Regulations guide professionals to change their practices, but code- and standard-setting bodies are largely reactive entities.

- Because the construction industry is so strongly influenced by codes and standards, it is often slow to change.

- Code changes, while necessary to address the altered climate hazards coming in future decades, will not be the only way we will need to address climate-related challenges.

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Projected Climate Hazards in NYS

- New York State has a humid continental climate with a wide range of climate conditions, influenced variously by Atlantic maritime exposure, the proximity of the Great Lakes, and mountainous regions.
- Historic average annual temperatures vary from around 40˚ F in the Adirondacks to about 55˚ F in New York City.
- More than 40 inches of snow per year is the statewide average, but maximum snowfall varies regionally, from more than 175 inches in some northern and western areas to less than 36 inches in the New York City metro region.
- The state experiences extremes of heat and cold, intense precipitation and flooding, and coastal storms with high variability across the state.

Uncertainty and Precaution

- Climate scientists can say with a high level of confidence that the future climate will differ from historic trends.
- Building professionals should not expect forecasts of the precise level of climate change in a particular location.
- Appropriate design will be critical for a plausible range of conditions, bearing in mind that historically based standards and codes do not yet reflect this range of conditions, and may not for several years.
- New York State faces a range of climate hazards due to its size and diverse geophysical characteristics of the state.
- The climate will not simply reset to a new, static normal; change is projected to unfold for decades. The new “normal” is dynamic.

Hurricanes / Tropical Storms

IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Hurricanes / Tropical Storms

- While impacts are most concentrated in New York City and Long Island, hurricanes and tropical storms have historically caused severe damage throughout New York State.

- Along with the rest of the eastern seaboard, New York has been experiencing a period of heightened hurricane activity since 1995.

- Additionally, it is more likely than not that the number of the most intense hurricanes will increase in the North Atlantic, and intense precipitation from hurricanes will likely increase as well.

- Storm surge is a type of flooding caused by wind-driven water during tropical storms, hurricanes, and nor'easters, particularly if they occur at high tide.

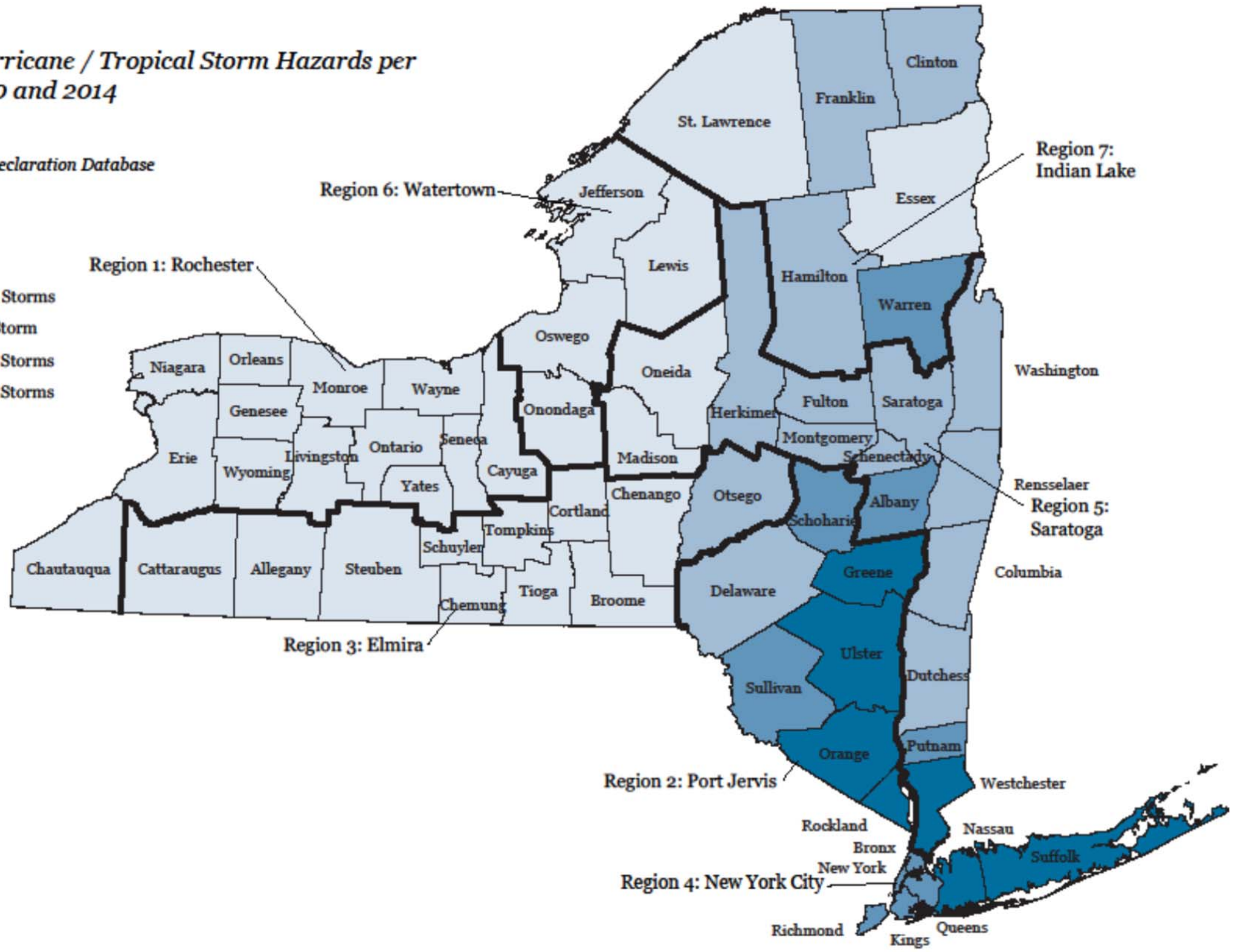
Total Number of Hurricane / Tropical Storm Hazards per County between 1960 and 2014

Data Source:

FEMA Presidential Disaster Declaration Database

Legend:

- 0 Hurricanes / Tropical Storms
- 1 Hurricane / Tropical Storm
- 2 Hurricanes / Tropical Storms
- 3 Hurricanes / Tropical Storms



Flooding

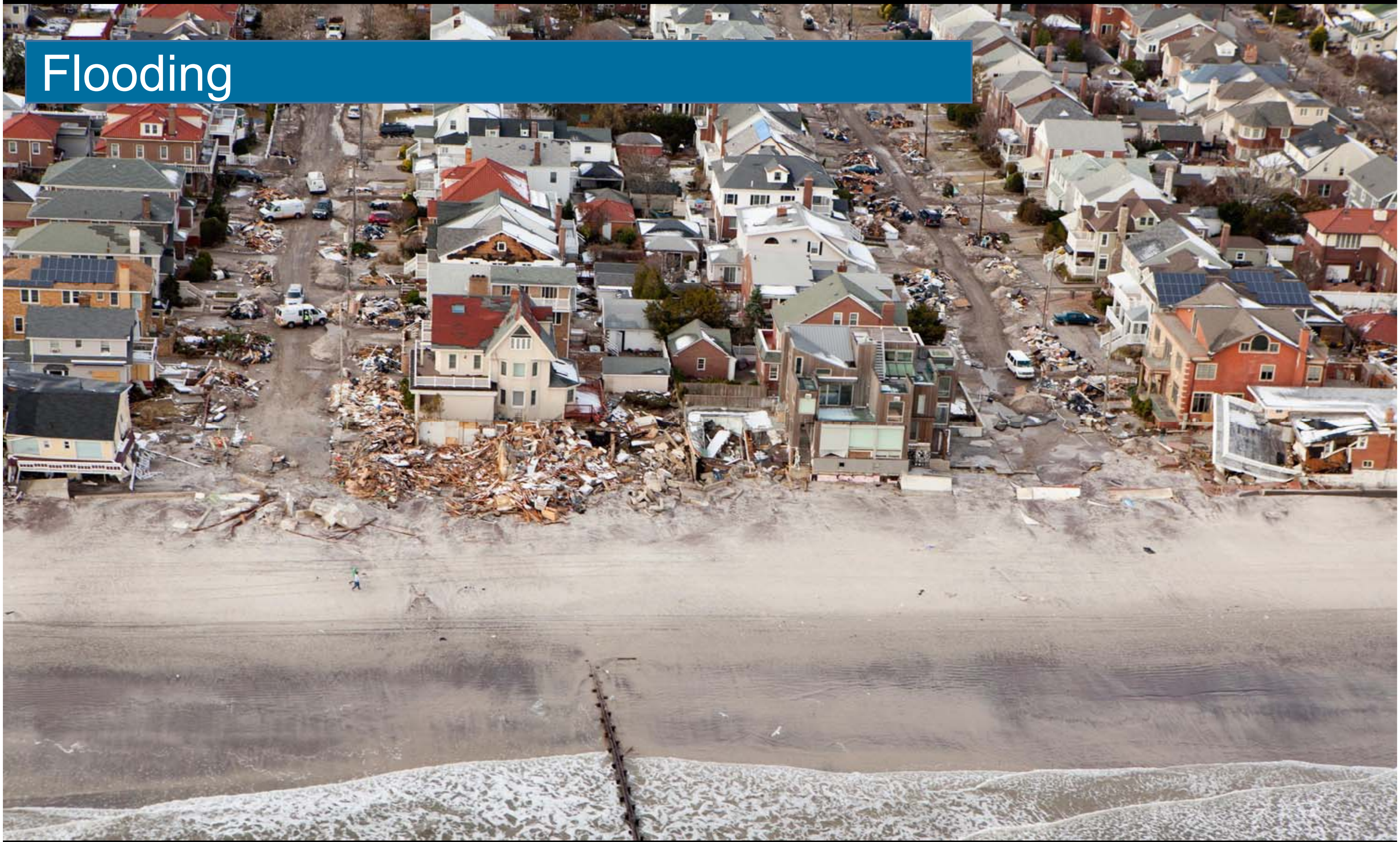


IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Flooding

- Total precipitation in New York State ranges from an average of 30 inches per year in parts of Western New York to around 50 inches per year in parts of the Adirondacks, Catskills, Tug Hill Plateau, and New York City metro area.

- Precipitation is projected to increase in the coming decades, with the greatest increases in the northern parts of the state.

- This wetter climate may intensify flooding and other hazards.

- Inland floods occur regularly in every New York county and are most commonly caused by rain or snow melt beyond the capacities of soils to absorb the water and stream/rivers to remove it.

Future Days with More Than 1” Rainfall in a Day

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 5 days/year)	4	5 to 5	6	4	5 to 5	6	4	5 to 6	7
Region 2: Port Jervis (Average of 12 days/year)	11	12 to 13	14	12	13 to 14	15	12	13 to 15	16
Region 3: Elmira (Average of 6 days/year)	6	6 to 7	7	6	6 to 7	8	6	7 to 8	8
Region 4: New York City (Average of 13 days/year)	13	14 to 15	16	13	14 to 16	17	14	15 to 17	18
Region 5: Saratoga (Average of 10 days/year)	10	10 to 11	12	10	11 to 12	13	10	11 to 13	14
Region 6: Watertown (Average of 6 days/year)	6	7 to 8	8	7	7 to 8	9	7	7 to 9	10
Region 7: Indian Lake (Average of 7 days/year)	7	7 to 8	9	7	8 to 9	10	8	8 to 10	11

Future Days with More Than 2” Rainfall in a Day

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 0.6 days/year)	0.6	0.6 to 0.7	0.8	0.5	0.6 to 0.8	0.9	0.5	0.6 to 0.9	1
Region 2: Port Jervis (Average of 2 days/year)	2	2 to 2	3	2	2 to 3	3	2	2 to 3	3
Region 3: Elmira (Average of 0.6 days/year)	0.6	0.7 to 0.9	1	0.7	0.8 to 1	1	0.7	0.8 to 1	1
Region 4: New York City (Average of 3 days/year)	3	3 to 4	5	3	4 to 4	5	3	4 to 5	5
Region 5: Saratoga (Average of 1 day/year)	1	1 to 2	2	1	1 to 2	2	1	1 to 2	2
Region 6: Watertown (Average of 0.8 days/year)	0.6	0.7 to 1	1	0.7	0.7 to 1	1	0.7	0.8 to 1	1
Region 7: Indian Lake (Average of 0.8 days/year)	0.7	0.8 to 1	1	0.8	0.9 to 1	1	0.8	0.9 to 1	1

Severe Storms

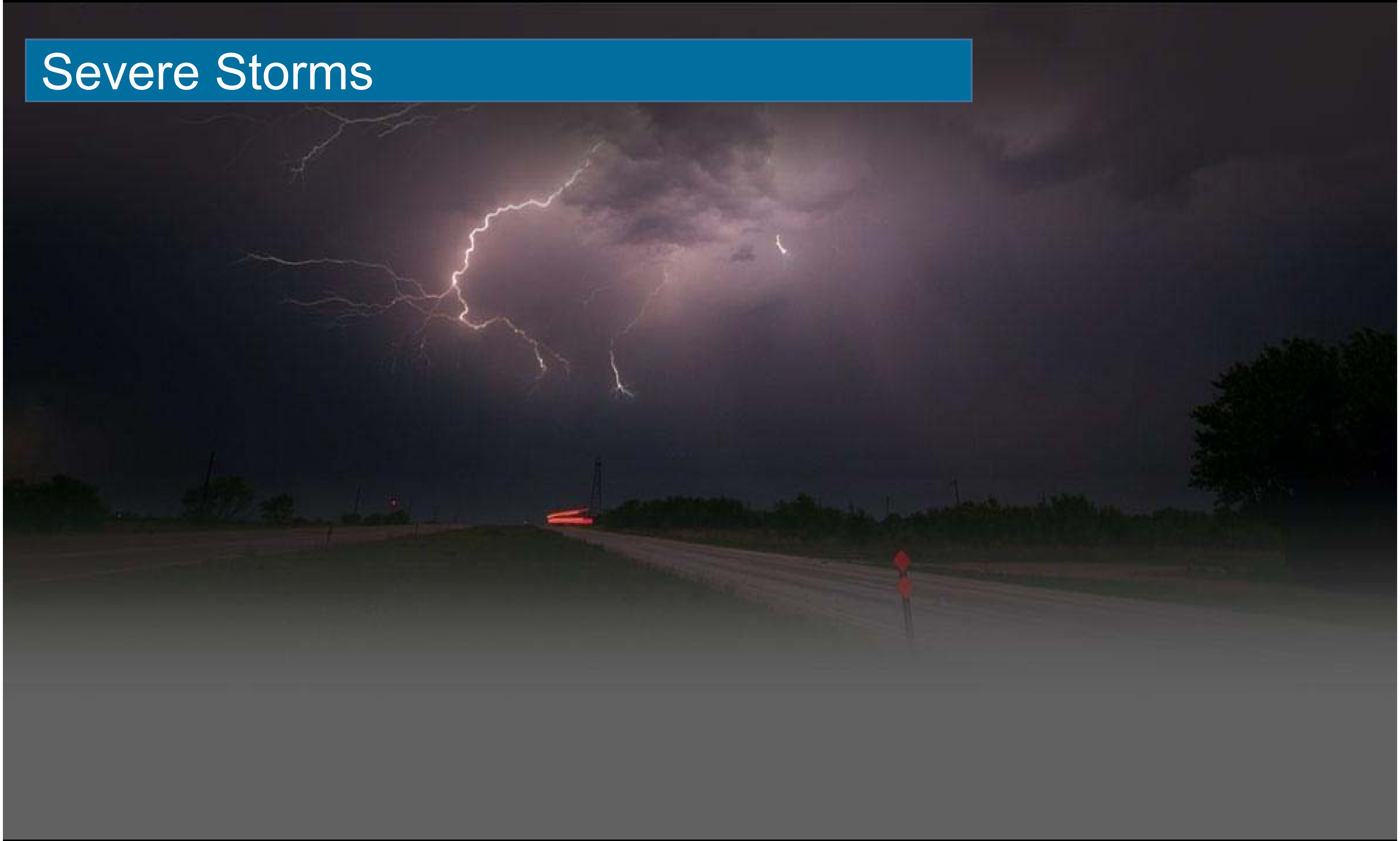


IMAGE SOURCE: READY.GOV THUNDERSTORMS & LIGHTNING

Severe Storms

- Severe storms such as thunderstorms have been and continue to be common throughout the state, with greatest frequency in Western and Central New York.

- Severe storms are likely to increase due to warming temperatures and increased precipitation.

- Although the projected total annual precipitation increases are relatively small, larger increases are expected in the frequency, intensity, and duration of extreme precipitation events.

Winter Storms

IMAGE SOURCE: NY.GOV

Winter Storms

- Historic winter precipitation has been highly variable, obscuring historic trends in annual snowfall.
- Seasonal ice cover on the Great Lakes has decreased about 8% per year over the past three decades, which suggests that lake effect snow will increase in coming decades.

Future Days Under 32ºF

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 133 days/year)	99	103 to 111	116	78	84 to 96	102	59	68 to 88	97
Region 2: Port Jervis (Average of 138 days/year)	106	108 to 116	120	79	86 to 100	108	59	65 to 89	101
Region 3: Elmira (Average of 152 days/year)	119	122 to 130	134	94	100 to 114	120	72	79 to 103	116
Region 4: New York City (Average of 71 days/year)	50	52 to 58	60	37	42 to 48	52	25	30 to 42	49
Region 5: Saratoga (Average of 155 days/year)	123	127 to 136	139	98	104 to 119	125	77	84 to 109	120
Region 6: Watertown (Average of 147 days/year)	116	119 to 126	130	96	102 to 113	119	78	85 to 104	114
Region 7: Indian Lake (Average of 193 days/year)	159	162 to 172	177	131	138 to 154	161	107	118 to 143	156

Sea Level Rise

IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Sea Level Rise

- While pre-industrial sea level rise was 0.34 to 0.43 inches/decade, sea level rise in New York's coastal areas and the tidal Hudson has been about 1.2 inches/decade over the last 100 years.

- An additional rise of 1-10 inches by the 2020s, 5-30 inches by the 2050s, and 10-58 inches by the 2080s is projected.

- As sea levels rise, coastal flooding during storms will also increase in frequency, intensity, and duration.

Future Sea Level Rise Hazards (inches)

ClimAID Region (Analyzed City)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 4 (at New York City)	2	4 to 8	10	8	11 to 21	30	13	18 to 39	58
Regions 2 and 5 (at Troy Dam)	1	3 to 7	9	5	9 to 19	27	10	14 to 36	54

Heat Waves

IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Heat Waves

- Temperatures have been rising each decade for the past century. They are projected to rise more quickly in the coming decades, with the greatest warming projected to occur in the northern part of the state.

- Temperatures are projected to increase across the state by 2.0-3.4° F by the 2020s, 4.1-6.8° F by the 2050s, and 5.3-10.1° F by the 2080s.

- Summers are expected to be more intense, and winters milder; hot summer conditions are expected to arrive three weeks earlier and last three weeks longer.

Future Days Over 90ºF

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 8 days/year)	12	14 to 17	19	18	22 to 34	42	22	27 to 57	73
Region 2: Port Jervis (Average of 12 days/year)	16	19 to 25	27	24	31 to 47	56	31	38 to 77	85
Region 3: Elmira (Average of 10 days/year)	15	17 to 21	23	22	26 to 41	47	28	33 to 67	79
Region 4: New York City (Average of 18 days/year)	24	26 to 31	33	32	39 to 52	57	38	44 to 76	87
Region 5: Saratoga (Average of 10 days/year)	14	17 to 22	23	22	27 to 41	50	27	35 to 70	82
Region 6: Watertown (Average of 3 days/year)	5	6 to 8	10	9	12 to 21	26	12	17 to 44	57
Region 7: Indian Lake (Average of 0.3 days/year)	0.5	0.8 to 2	2	2	3 to 6	10	3	5 to 19	27

Future Number of Heat Waves

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Currently 0.7 per year)	2	2 to 2	2	2	3 to 4	5	3	3 to 8	8
Region 2: Port Jervis (Currently 1 per year)	2	3 to 3	4	3	4 to 6	8	4	5 to 9	9
Region 3: Elmira (Currently 1 per year)	2	2 to 3	3	3	3 to 6	6	3	4 to 9	9
Region 4: New York City (Currently 2 per year)	3	3 to 4	4	4	5 to 7	7	5	6 to 9	9
Region 5: Saratoga (Currently 1 per year)	2	2 to 3	4	3	4 to 6	7	4	5 to 8	9
Region 6: Watertown (Currently 0.2 per year)	0.6	0.8 to 0.9	1	1	1 to 3	3	1	2 to 6	7
Region 7: Indian Lake (Currently 0 per year)	0	0.1 to 0.2	0.2	0.2	0.3 to 0.7	1	0.2	0.5 to 2	3

Future Duration of Heat Waves

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 4 days)	4	4 to 4	4	4	4 to 5	5	4	5 to 6	6
Region 2: Port Jervis (Average of 4 days)	4	5 to 5	5	5	5 to 6	6	5	5 to 7	8
Region 3: Elmira (Average of 4 days)	4	4 to 5	5	5	5 to 5	5	5	5 to 6	7
Region 4: New York City (Average of 4 days)	5	5 to 5	5	5	5 to 6	6	5	5 to 7	8
Region 5: Saratoga (Average of 4 days)	4	5 to 5	5	5	5 to 6	6	5	5 to 7	9
Region 6: Watertown (Average of 4 days)	3	4 to 4	4	4	4 to 4	5	4	4 to 6	6
Region 7: Indian Lake (Average of 3 days)	3	3 to 4	4	3	3 to 4	4	4	4 to 5	5

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Risks of Cascading Effects

- Buildings have fundamentally linked interactions with infrastructure, occupants, and climate that can yield cascading effects with impacts on people in buildings.
- Cascading effect occurs when failure in one system triggers a failure in another.
- Buildings can help decouple community-scale risks. For example, green roofs can lower urban heat island effect, reduce cooling energy demand, and capture rainwater to reduce urban flooding.

Impacts of Hurricanes / Tropical Storms

IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Impacts of Hurricanes / Tropical Storms

- Hurricanes and tropical storms bring high winds, intense rainfall, and, in coastal areas, storm surge.
- High winds cause damage to buildings in three main ways:

  1. The first type of damage is direct, for example when the building slides off its foundation, the building overturns off its foundation, the structural frame racks, or roof uplift occurs

  2. The second type is impact damage from wind-borne debris, usually to brittle materials like glass

  3. The third type of damage is collateral, in which another structure or a tree falls on a building

Impacts Of Flooding

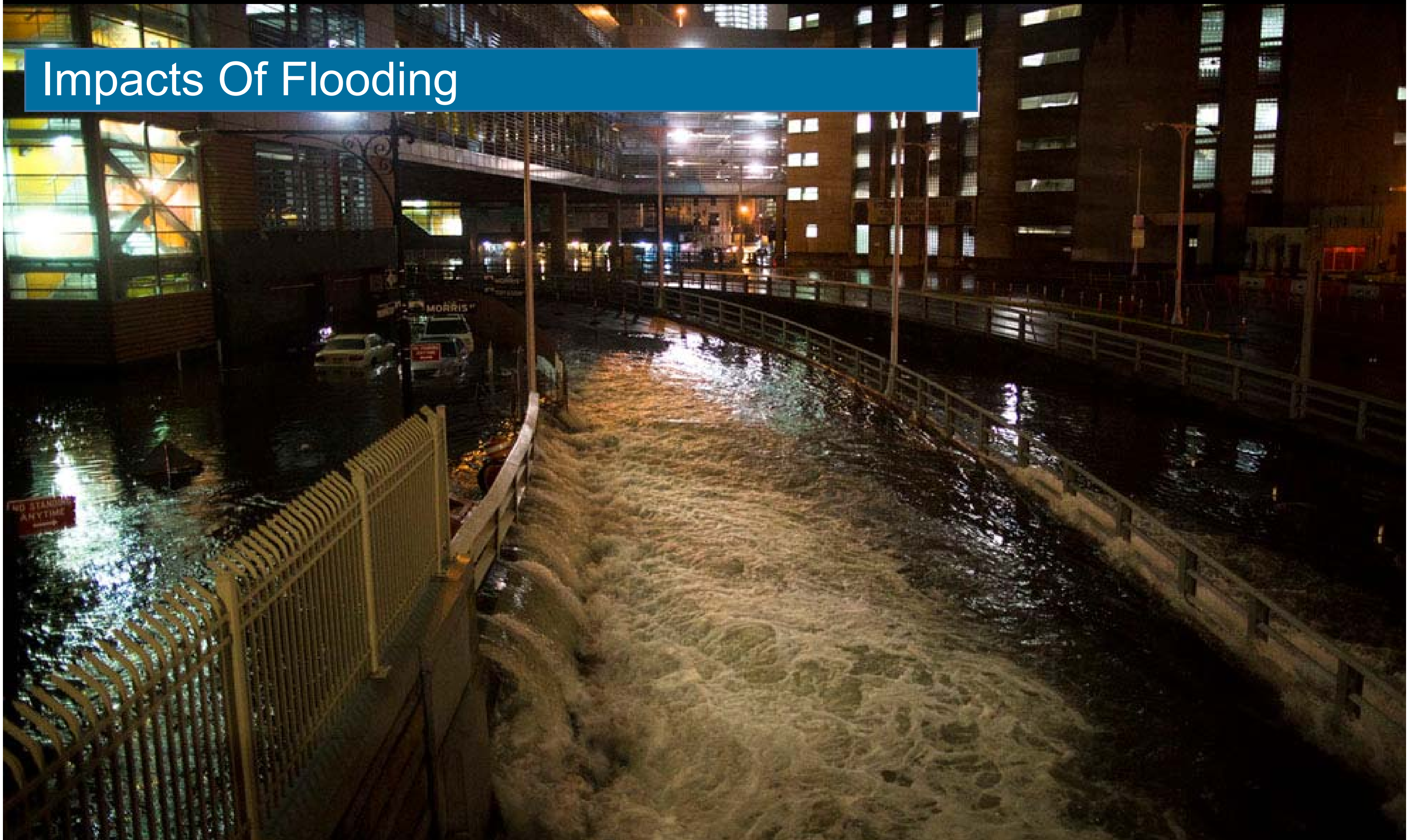

IMAGE SOURCE: NATIONAL WEATHER SERVICE (WEATHER.GOV)

Impacts of Flooding

- Flooding is one of the most significant climate-change threats to buildings.
- Approximately 700,000 people live in areas designated as “flood-prone” in New York State, and millions more work, travel through, or recreate in flood-prone areas.
- Sea level rise coupled with storm surge and flooding can inundate roads, isolate communities, and damage buildings and infrastructure.
- Impacts are greatest in urban areas with high percentages of impermeable surfaces because there is little capacity for absorption of excess water.
- Flooding can also have also multiple economic impacts on the buildings sector.

Impacts of Severe Storms

IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Impacts of Severe Storms

- Severe land-based storms bring high winds and intense rainfall.
- As precipitation levels increase, building failures and flooding will increase. Wind-driven rain is more likely to penetrate roofs, walls, apertures, and foundations.
- Damage to the building exterior may create cascading risk, whereby an envelope breach increases the possibility of cladding system failure, as well as damage to the structure, building systems, and building contents.

Impacts of Winter Storms

IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Impacts of Winter Storms

- In the areas of the state that may see increased winter precipitation, buildings may see increased roof loading due to larger snowfall during storm events.
- Ice dam formation during cold weather may damage eaves and allow water to penetrate roofing.
- Snow buildup at a building perimeter can drive moisture into wall assemblies.
- Snow and ice accumulation may threaten electrical distribution infrastructure at the community level, leading to power outages.

Impacts Of Sea Level Rise

IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Impacts of Sea Level Rise

- In coastal and tidal areas of the state, levees and seawalls may be overtopped or undermined, and other water control infrastructure may become overwhelmed, which will increase the threat of flooding and damage to buildings.

- Increased erosion due to sea level rise may shift shoreline position sufficiently to destabilize foundations or affect infrastructure.

Impacts of Heat Waves

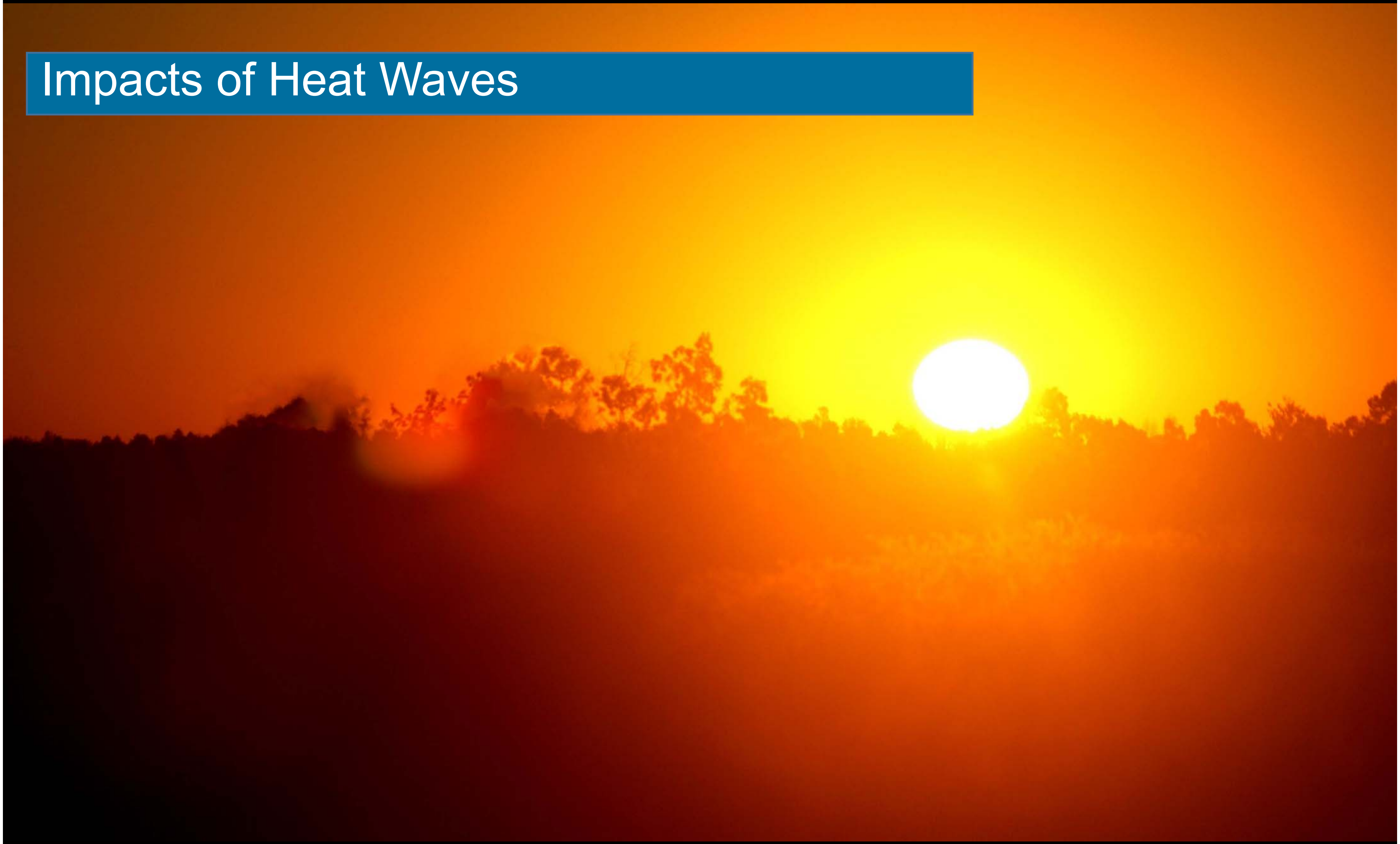

IMAGE SOURCE: RESEARCH.NOAA.GOV

Impacts of Heat Waves

- Increasing outdoor temperatures will impact the indoor environment.
- Warmer and more humid conditions increase energy demand (particularly for electricity) for mechanical cooling in summer, exacerbating the warming trends of global climate change by increasing fossil fuel consumption.
- Many buildings have no means of natural ventilation, let alone space cooling, during power outages.
- On the exteriors of buildings, rising temperatures may reduce the service life of building cladding materials.
- An intensified urban heat island on the outside of buildings will further increase demand for cooling.

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Adapting Buildings to a Changing Climate

- A crucial part of the adaptation process is identifying and developing appropriate adaptation strategies or measures.
- Strategies that limit exposure to risk and take advantage of the potential opportunities of climate change must respond to the specifics of place.
- To this end, adaptation strategies for different projects vary.

Prioritization of Investment Over Time

- Whether and when to adapt is a complex decision that must consider a building's lifetime, program, importance, and materials and systems.
- Adaptation is needed only for buildings that will still be standing and usable when the climate change impacts occur.
- Adaptation does not always have a clear and certain short-term return on investment.
- Adaptation strategies with collateral public benefits may be easier to implement and have a better return on investment

Parsing Futureproofing from Current Benefits

- Adaptation strategies can be divided into strategies that only prepare a building for new or increased hazards in the future, and “no-regret” strategies that not only anticipate future needs but also provide auxiliary benefits under current climate conditions.
- Strategies that provide current benefits generally dovetail with sustainable and energy-efficient design practices.

Adaptations for Hurricanes / Tropical Storms

- The most critical design response to intense storms is to establish a continuous load path between walls, floors, roof, and foundation.
- A holistic design is important; otherwise, increasing strength in just one area may only change the mode of failure.
- Aerodynamically efficient building massing and form can help to deflect high winds and protect roof, walls, and openings.
- Hurricane shutters can protect building openings. Impact-resistant glazing resists breakage and prevents the life safety hazard of flying broken glass.
- A backup power supply ensures electricity continuity during hurricanes and tropical storms.

IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Adaptations for Flooding

- **Retreating** involves leaving high-risk coastal areas and maintaining protective setbacks from potentially hazardous areas.
- **Accommodating** allows water to collect and move without causing damage, displacement, or interruption.
- **Protecting** buildings from flooding and storm surge involves constructing structures like seawalls or soft structures like berms.

IMAGE SOURCE: NATIONAL WEATHER SERVICE (WEATHER.GOV)

Adaptations for Severe Storms

- Roofs should be designed with proper drainage for higher expected precipitation levels, and they should have sufficient slope or structural stiffness to prevent ponding.

- Drainage systems should shed water away from openings and building foundations.

- Additional protection against vapor penetration and water migration may be needed at the foundation, including below-slab membranes, vapor barriers at the interior of sub-grade walls, gravel backfill around foundation walls, and damp-proof courses of masonry.

- A backup power supply may be needed to ensure continuity during severe storms.

IMAGE SOURCE: GOVERNOR.NY.GOV

Adaptations for Winter Storms

- Strengthening roof structures to meet higher design snow loads will be important, as will appropriate eave detailing to protect against ice dams.
- Cladding material durability and maintainability should also be considered.
- Permeable paving or landscape approaches to help with snow thaw and drainage can help minimize moisture accumulation.
- A backup power supply may be needed to provide electricity continuity in winter storms.

IMAGE SOURCE: FEMA.GOV MEDIA LIBRARY

Adaptations for Heat Waves

- **Passive design**: Basic passive design strategies can help buildings make the most of climatic resources so that mechanical equipment runs as little as possible when creating comfortable conditions.
- **High-performing envelope**: A high-performance building envelope will reduce environmentally driven cooling loads.
- **Efficient HVAC equipment**: Higher overall temperatures and more frequent extreme heat events will increase the frequency and amount of mechanical cooling needed.
- **Backup power supply**: Battery backups and onsite energy production can ensure a continuous energy supply to provide space conditioning when needed.

IMAGE SOURCE: RESEARCH.NOAA.GOV

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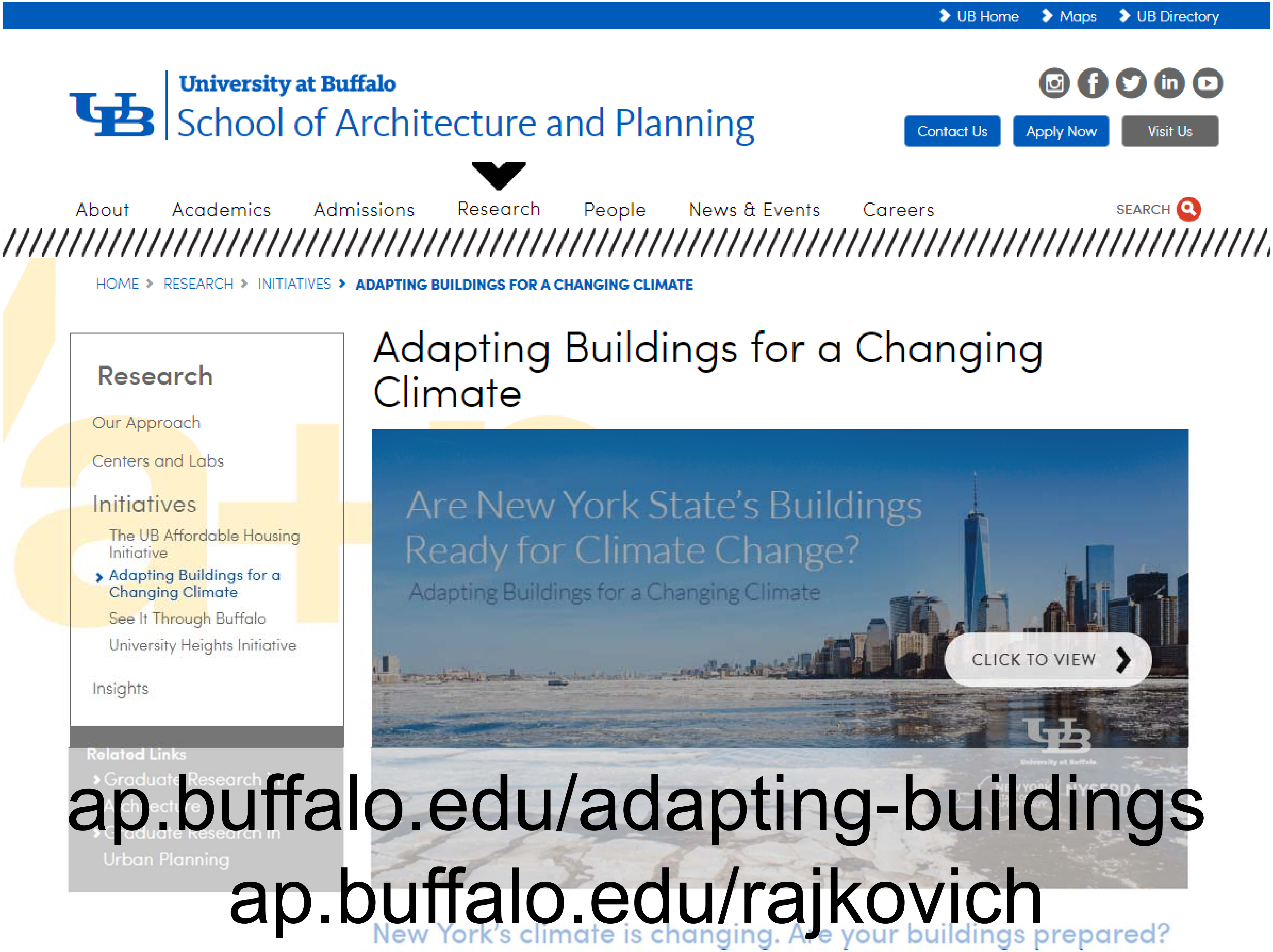

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