National Aeronautics and Space Administration

Building Climate Risk Assessments from Local Vulnerability and Exposure

Part 1: Theoretical Framework for Demand-Driven Climate Adaptation Support

Alex Ruane (NASA GISS) and Sanketa Kadam (NASA GISS & Columbia University)

September 19, 2023

About ARSET

About ARSET

- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**

- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.

AGRICULTURE

CLIMATE & RESILIENCE

DISASTERS

ECOLOGICAL CONSERVATION

HEALTH & AIR QUALITY

WATER RESOURCES

About ARSET Trainings

- Online or in-person
- Live and instructor-led or asynchronous and self-paced
- Cost-free
- Bilingual and multilingual options
- Only use open-source software and data
- Accommodate differing levels of expertise

- Visit the ARSET website to learn more.

Building Climate Risk Assessments from Local Vulnerability and Exposure

Overview

Why is Climate Risk Assessment Important?

- Climate change impacts and risks are becoming increasingly complex and more difficult to manage (IPCC AR6, 2022).
- Climate change impacts on infrastructure vary by region.
- Identifying at-risk assets and the types of climate conditions that drive problematic responses, stakeholders and scientists can co-develop risk information to suitably address those risks.

Credit: Scott Pena

Training Learning Objectives

By following the approaches described in this training, participants will be able to:

- Recognize the dramatic contextual nature of climate risk assessments and adaptation planning
- Identify components of their own system that are vulnerable or exposed to climate risks
- Work with stakeholders to construct climate risk information that is useful for their decision-making processes
- Use risk information to identify adaptation strategies for implementation

Prerequisites

- Fundamentals of Remote Sensing
- Introduction to NASA Resources for Climate Change Applications
- Selecting Climate Change Projection Sets for Mitigation, Adaptation and Risk Management Applications

Introduction to NASA Resources for Climate Change Applications

Part 1: Climate Change Monitoring & Impacts Using Remote Sensing and Modeled Data

Speakers: Sean McCartney & Amita Mehta

Part 2: Climate Change Future Scenarios, Impact Projection, and Adaptation

Wednesday, October 6, 2021

Speakers: Alex Ruane & Daniel Bader

- Introduction to NASA observational and modeling capabilities for the climate system
- Fundamentals of climate change assessment methods
- Background on key terms and assumptions, describing scenarios, climate impact sectors, adaptation decision support

Selecting Climate Change Projection Sets for Mitigation, Adaptation and Risk Management Applications

Part 1: What makes projection sets different?

Part 2: How do you choose a projection set for your application?

Tuesday, September 20, 2022

Speakers: Alex Ruane & Meridel Phillips

- Making sense of the huge number of available climate data and modeling products
- Identifying critical climate information needs for a given application
- Tracking uncertainties related to selecting a subset of datasets, models, scenarios, variables, and time periods, all the way through decision support

Training Outline

Part 1: Theoretical Framework for Demand-Driven Climate Adaptation Support

Tuesday, September 19, 2023

11:00–12:30pm and 3:00–4:30pm EDT

(UTC-4:00)

Part 2: Developing Climate Adaptation Support for NASA Centers

Thursday, September 21, 2023

11:00–12:30pm and 3:00–4:30pm EDT (UTC-4:00)

Homework

September 21, 2023 – Due October 5, 2023 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

Part 1 Objectives

By the end of Part 1, participants will be able to:

- Summarize the theory of demand-driven climate adaptation support
- List resources for adaptation support
- Recognize demonstrative examples of impact assessment based on empirical approaches and analysis of infrastructure

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to address all questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

Part 1 – Trainers

Alex Ruane

NASA Goddard Institute for Space Studies (GISS)

Sanketa Kadam

NASA GISS & Columbia University

Part 1

Theoretical Framework for Demand-Driven Climate Adaptation Support

Four Threads Throughout this Presentation:

T Thread 1: Basic Approach and Climate Risk Theory

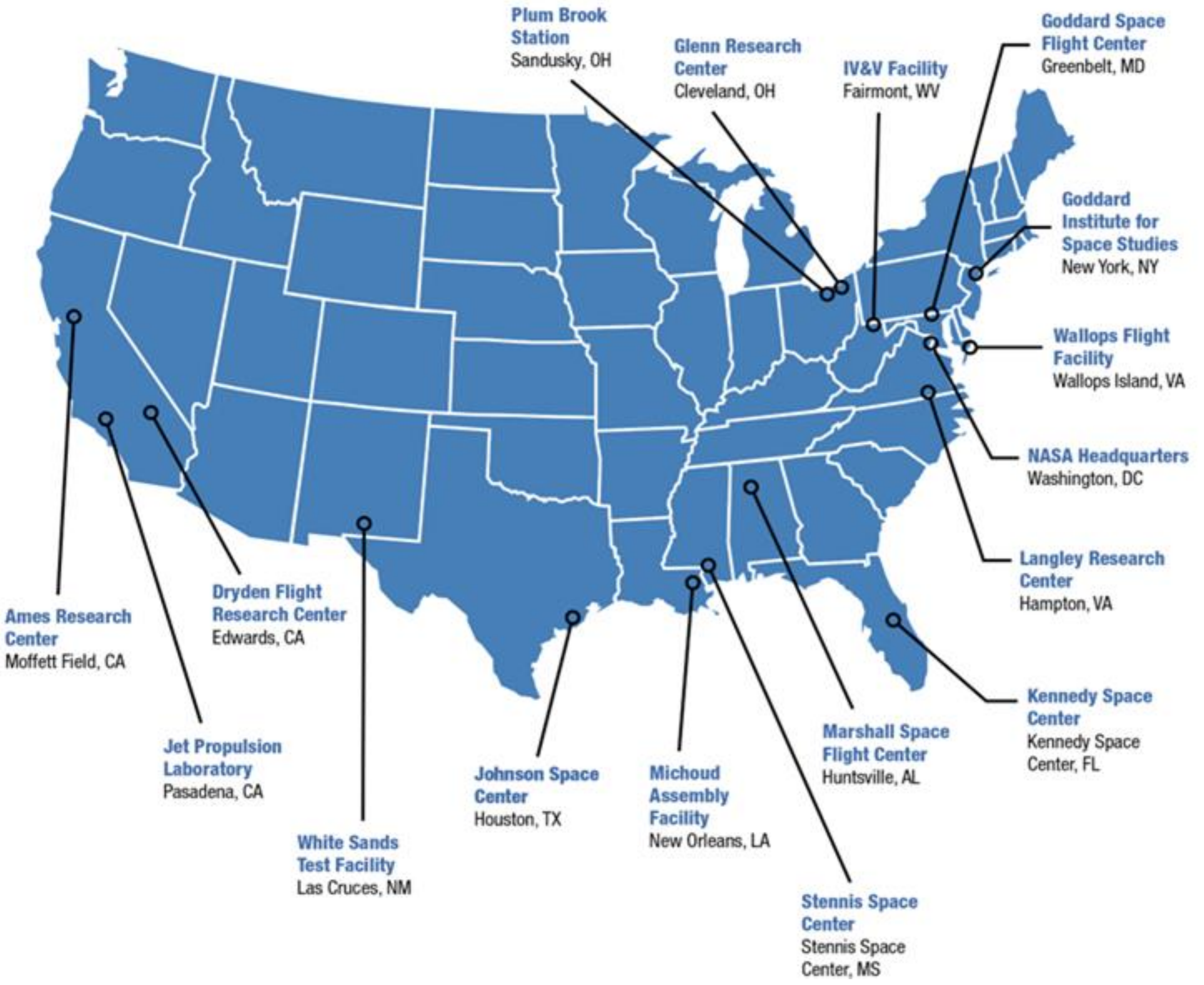
R Thread 2: Resources and Tools

D Thread 3: Demonstrative Examples

C Thread 4: End-to-end examples from the Climate Adaptation Science Investigators Phase 2 (CASI2) Initiative that is informing NASA Centers' efforts to increase resilience and adapt to climate risks.

The Climate Adaptation Science Investigators (CASI) Initiative

What are the climate threats to NASA facilities, and how can we prepare for future challenges?



Observed Climate Risk at NASA

Many NASA facilities have experienced climate and weather-related impacts in recent years.

Wildfires reached within a mile of JPL, 2009
Rosenzweig et al., 2014

Hurricane Sandy Damage to Wallops Flight Facility, October 2012

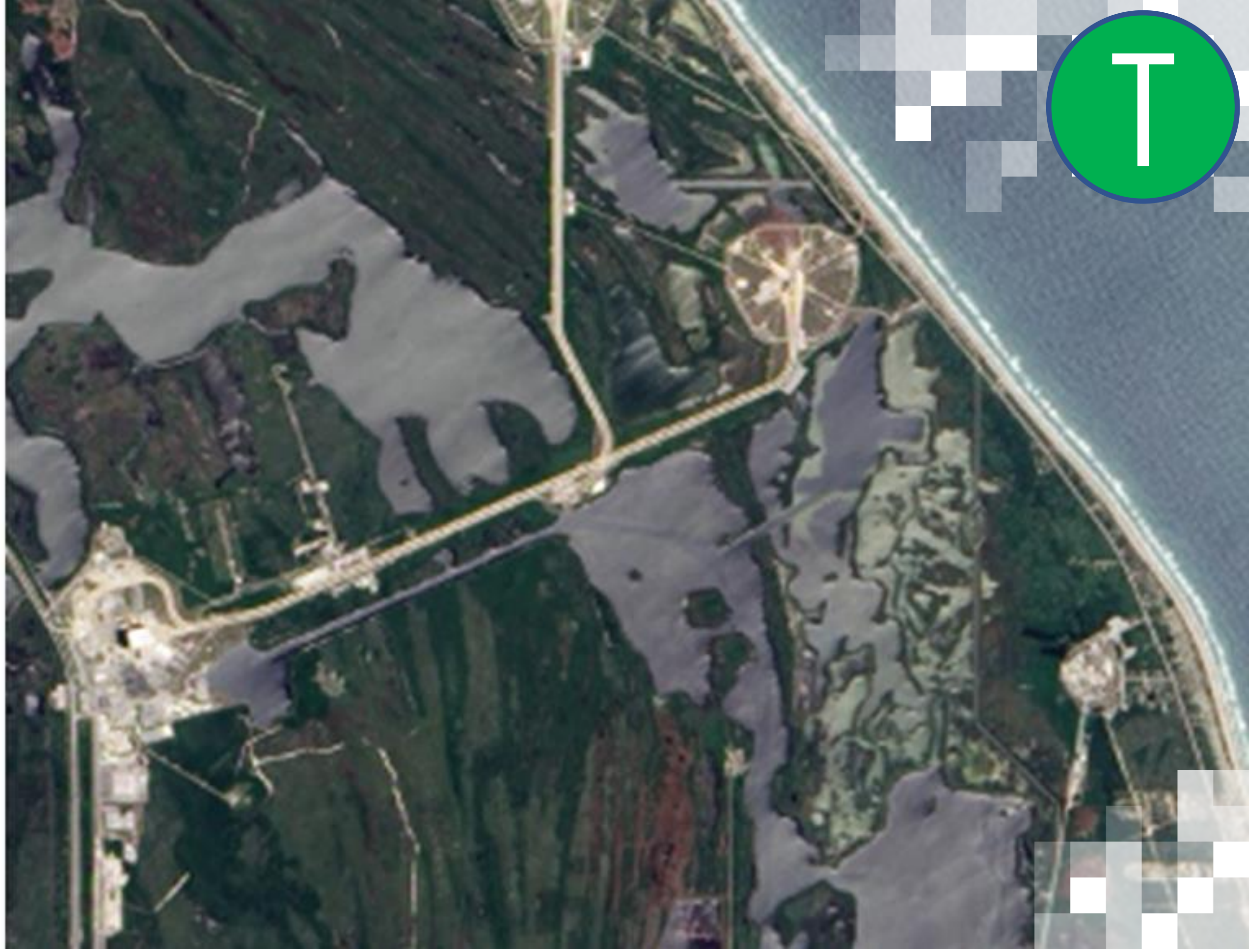
Michoud Assembly Facility Damage after Hurricane Zeta, October 2020

CASI Mission:

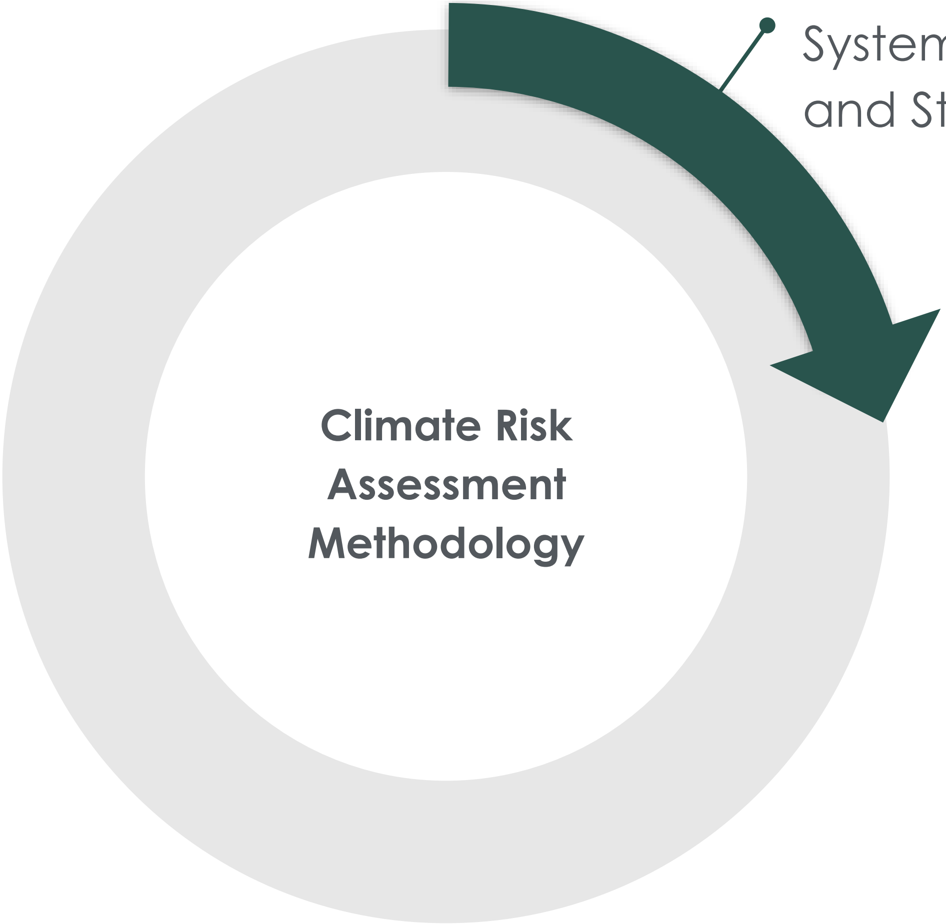
Provide the latest scientific research on climate change to help NASA facilities managers adapt to increasing climate risks in timely and effective ways.

- **CASI Workgroups** are a collaboration of NASA subject matter experts and infrastructure management (teams of ~10 members per center).
- **CASI provides** a portfolio of key current and future climate risk information for Center managers protecting operations, assets, and workforce in an around their Centers. These products are co-generated and linked to decisions.

Rosenzweig et al, 2023 (in prep) Climate Adaptation Science Investigators Workgroup (CASI): A Partnership between Scientists and Facility Managers to Enhance Climate Resilience at NASA

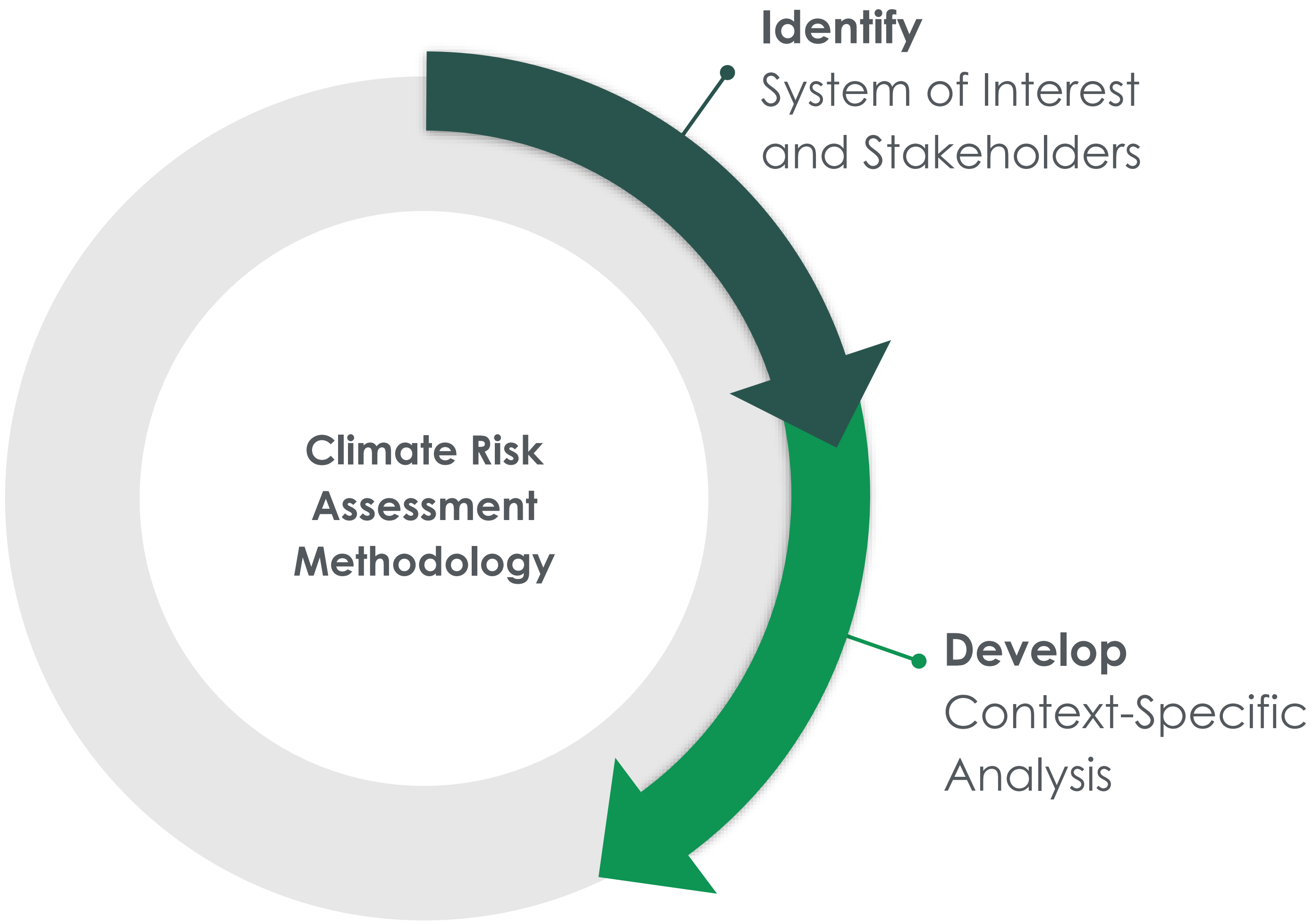


Climate Risk Assessment Theory



Identify
System of Interest
and Stakeholders

Adopted from Climate Risk Management (CRM) process from GIZ, adaptationcommunity.net



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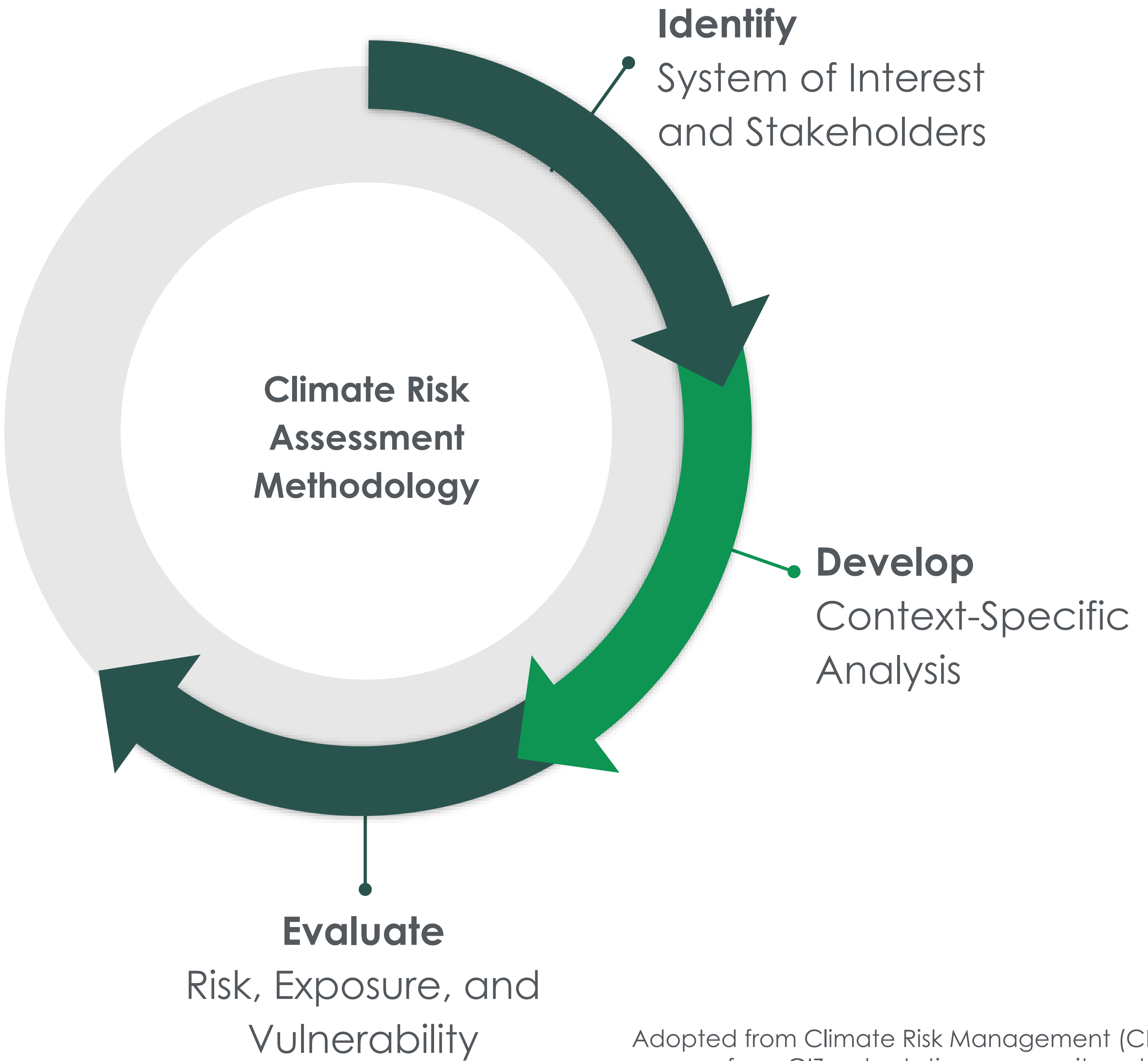

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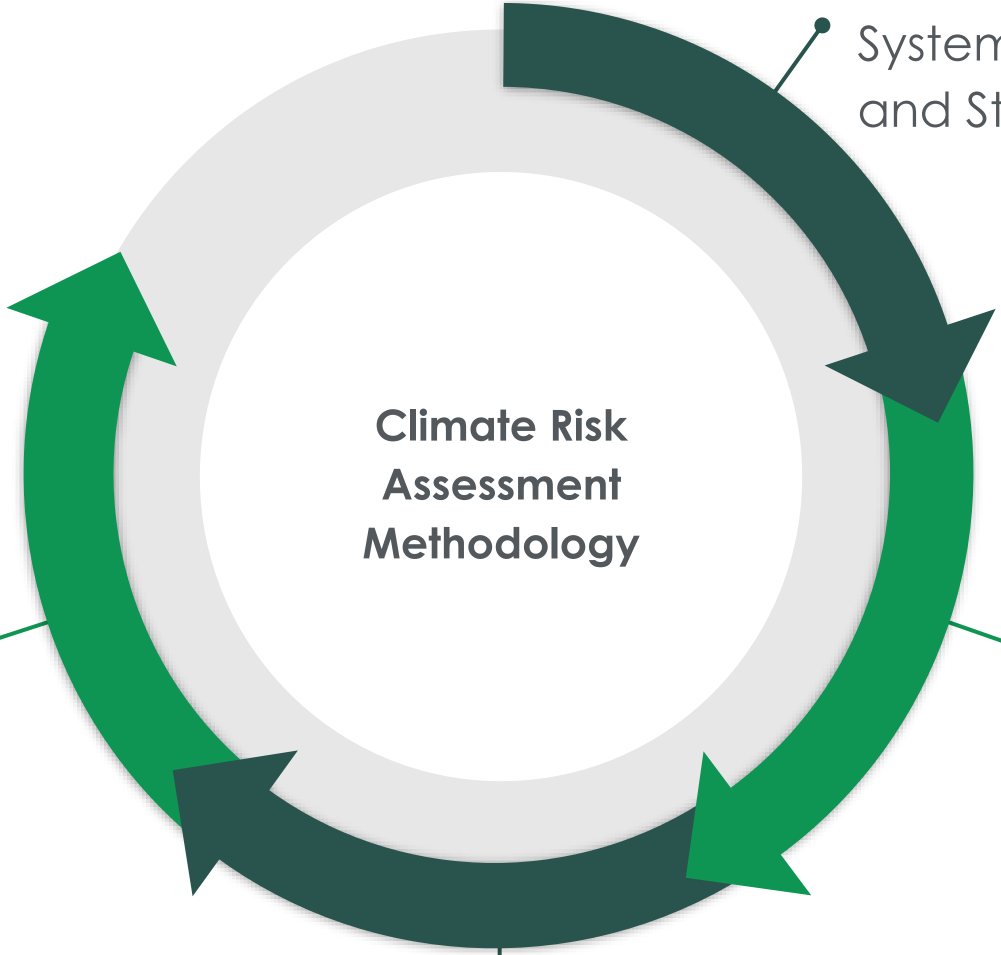

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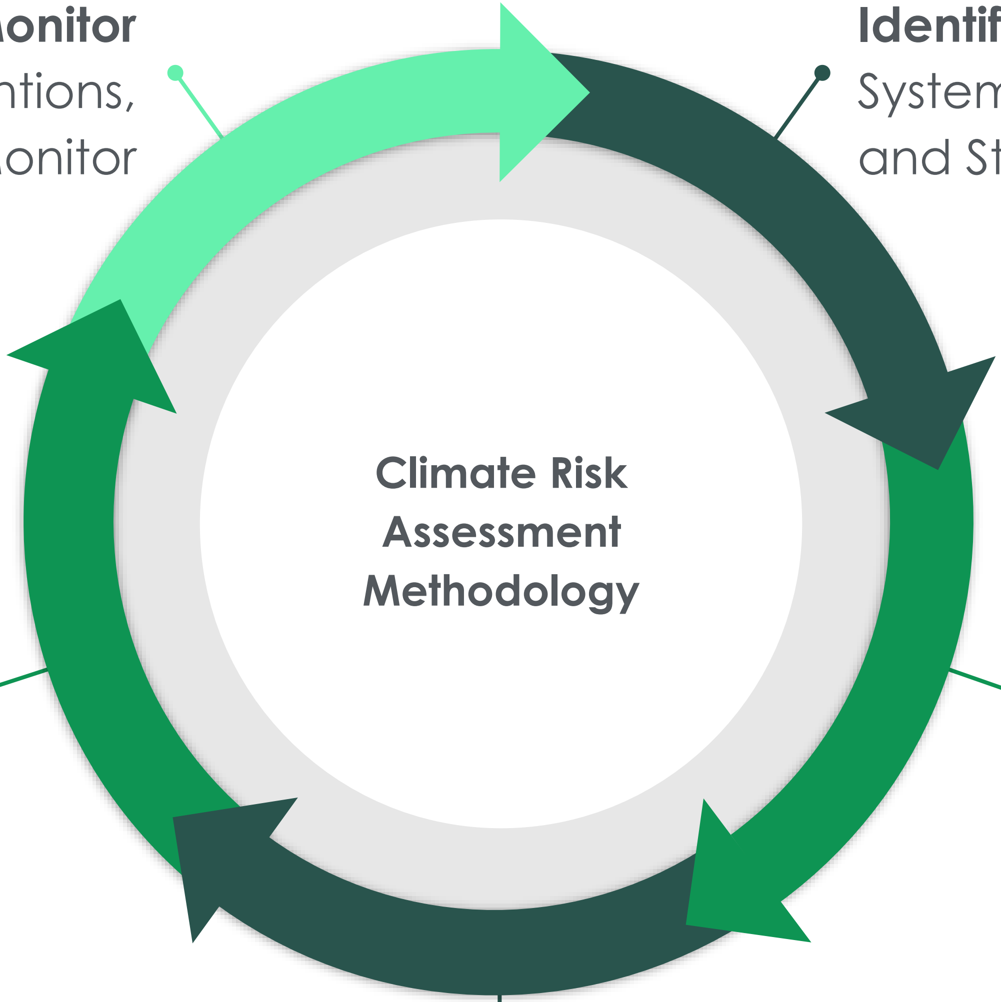


Identify
System of Interest and Stakeholders

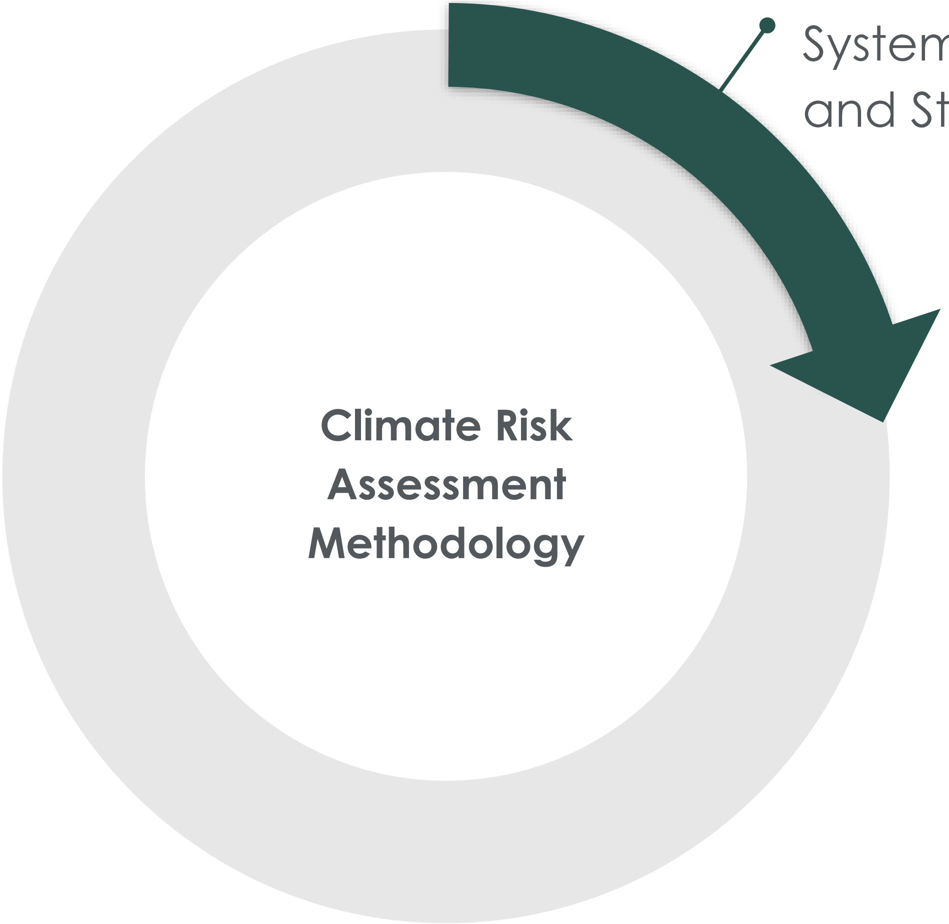
Develop
Context-Specific Analysis

Evaluate
Risk, Exposure, and Vulnerability

Assess
Magnitude and Frequency of Impacts

Implement & Monitor
Identify Interventions, Scales, and Monitor

Adopted from Climate Risk Management (CRM) process from GIZ, adaptationcommunity.net



Identify
System of Interest
and Stakeholders

Identify

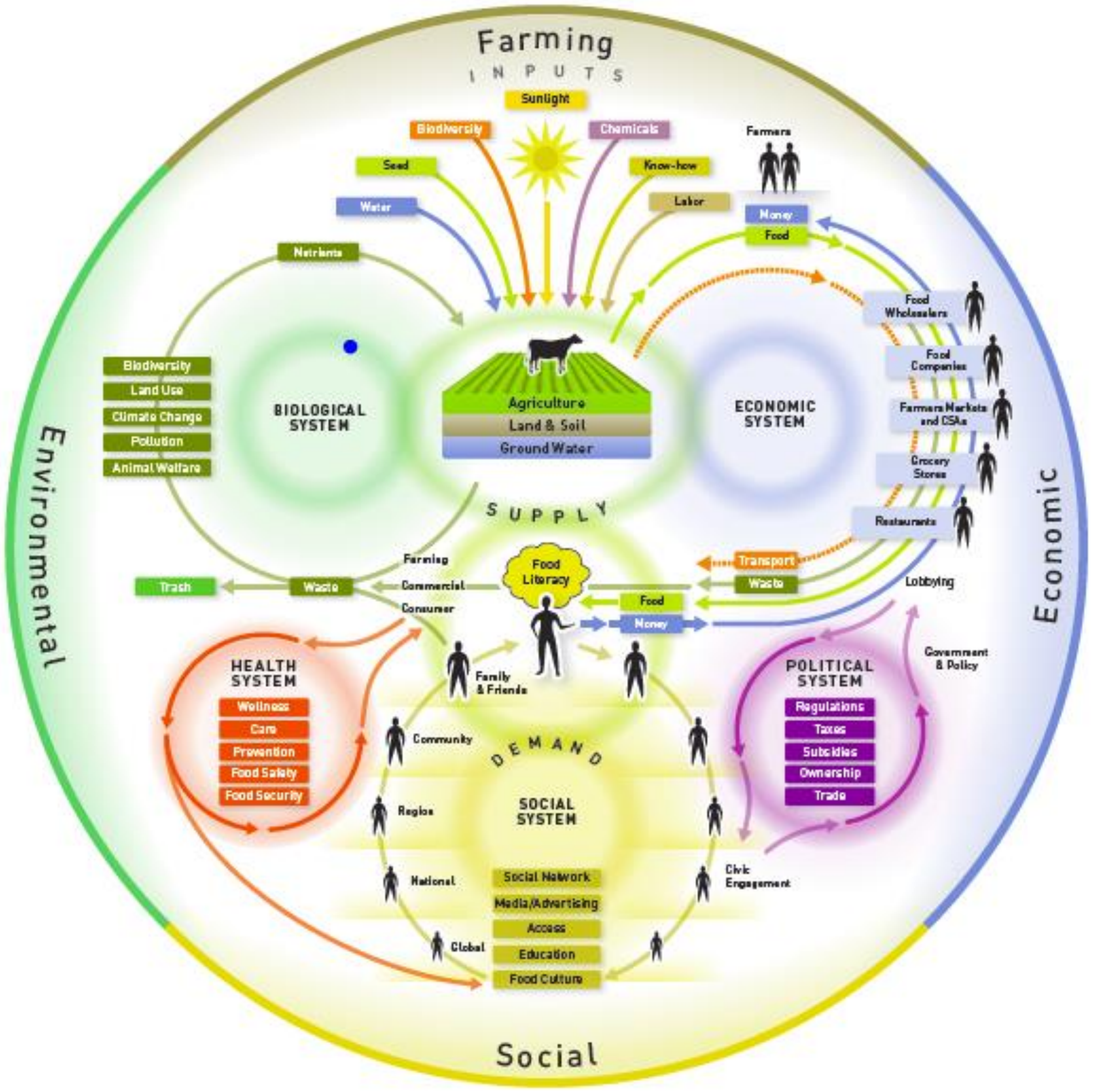
- Identify the stakeholders by their roles and as individual people
  - Clarify their interest, influence, and competing constraints
  - Connect with any potentially overlapping efforts
- Identify sector problem to address and system scale
- Identify time horizons of decisions

NASA Wallops Flight Facility, Wallops Island, Virginia

Understanding Complex Systems

Different stakeholders have unique Points of leverage

(e.g., in food system)

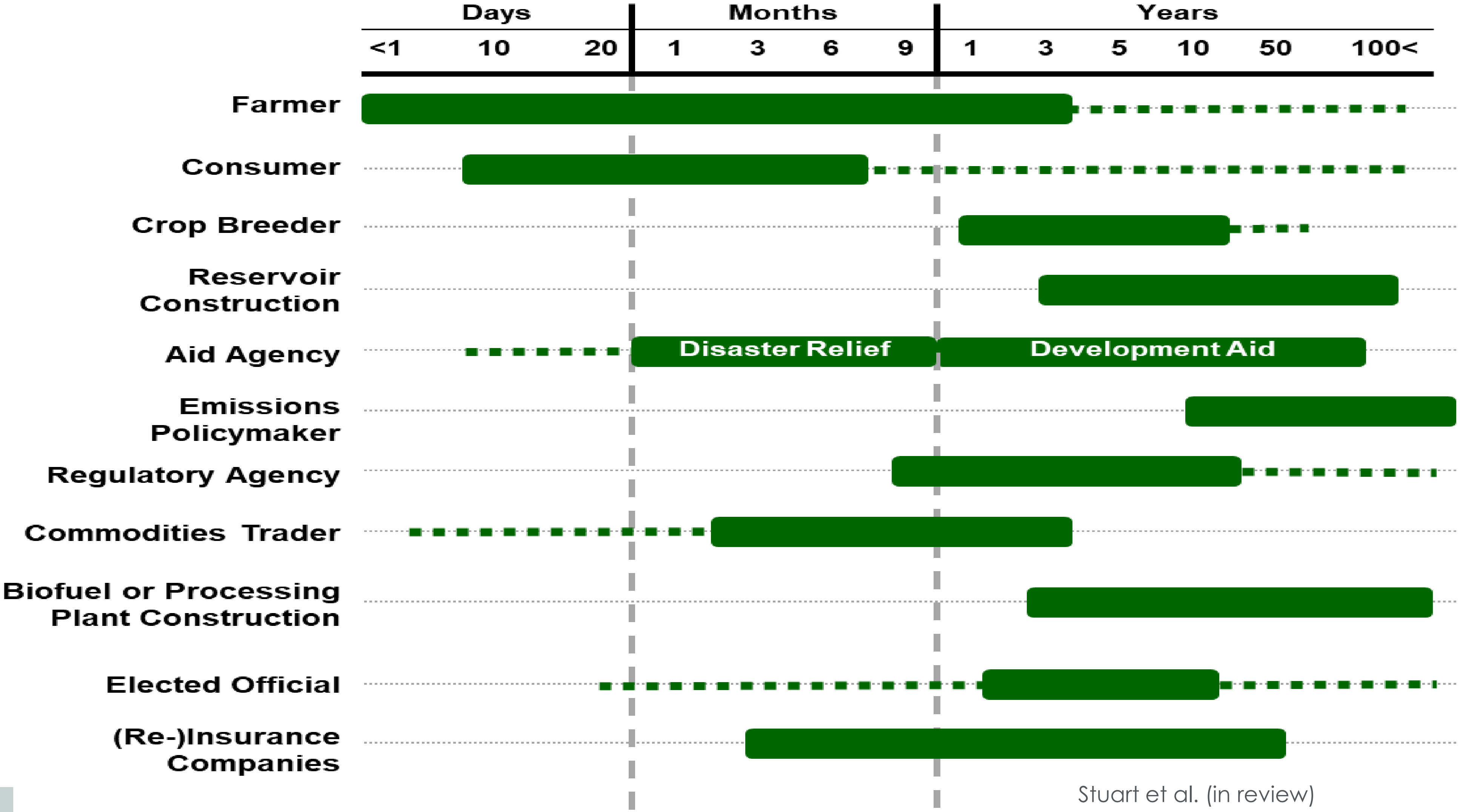


http://www.nourishlife.org/teach/food-system-tools/

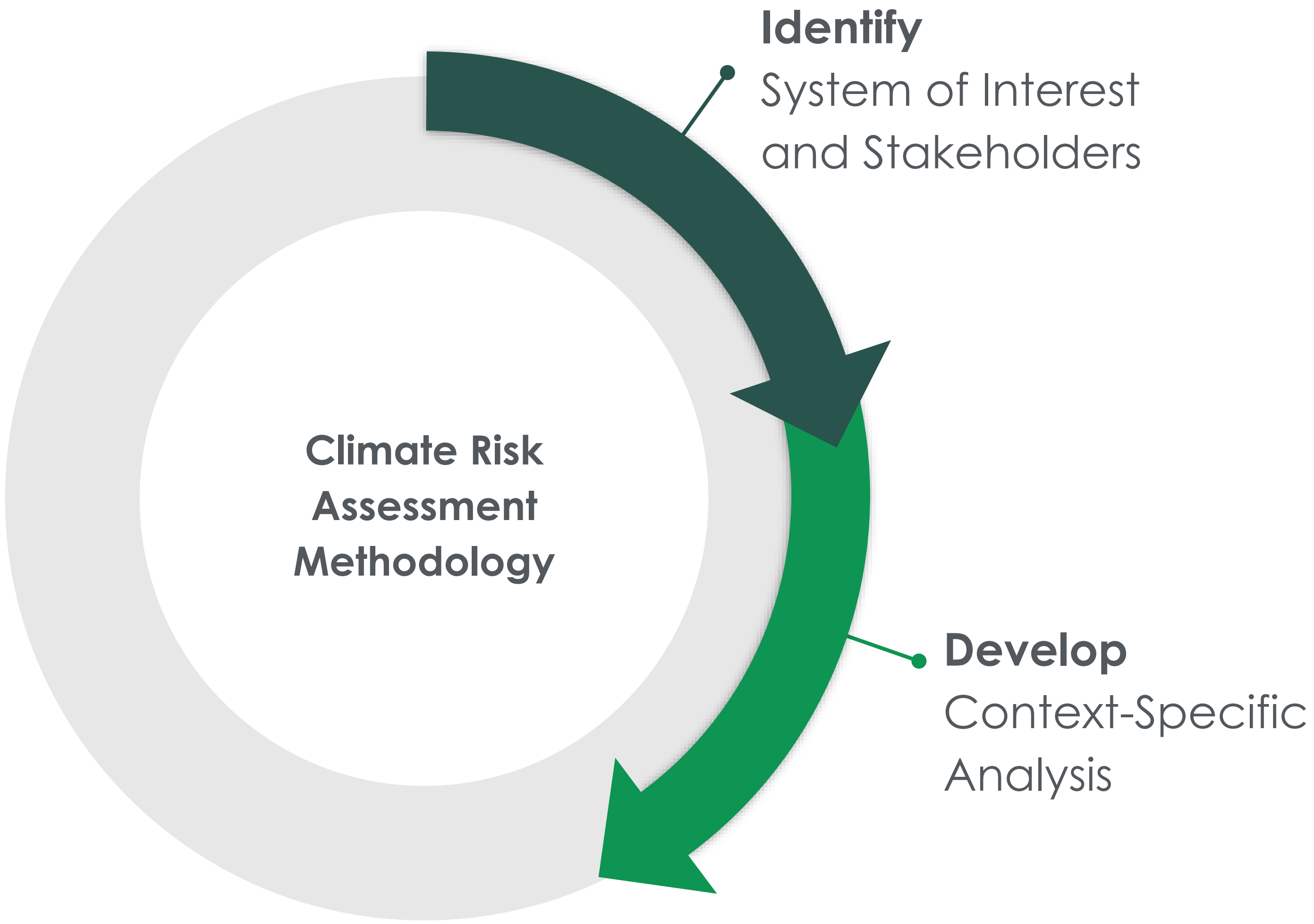
Matching Time Scales with Decision Scales

Stakeholder decisions have unique horizons

(e.g., in food system)



Stuart et al. (in review)


Identify
System of Interest and Stakeholders
Climate Risk Assessment Methodology
Develop
Context-Specific Analysis

Develop

- **Context-specific analysis** is more likely to be successful and is more appealing to stakeholders.

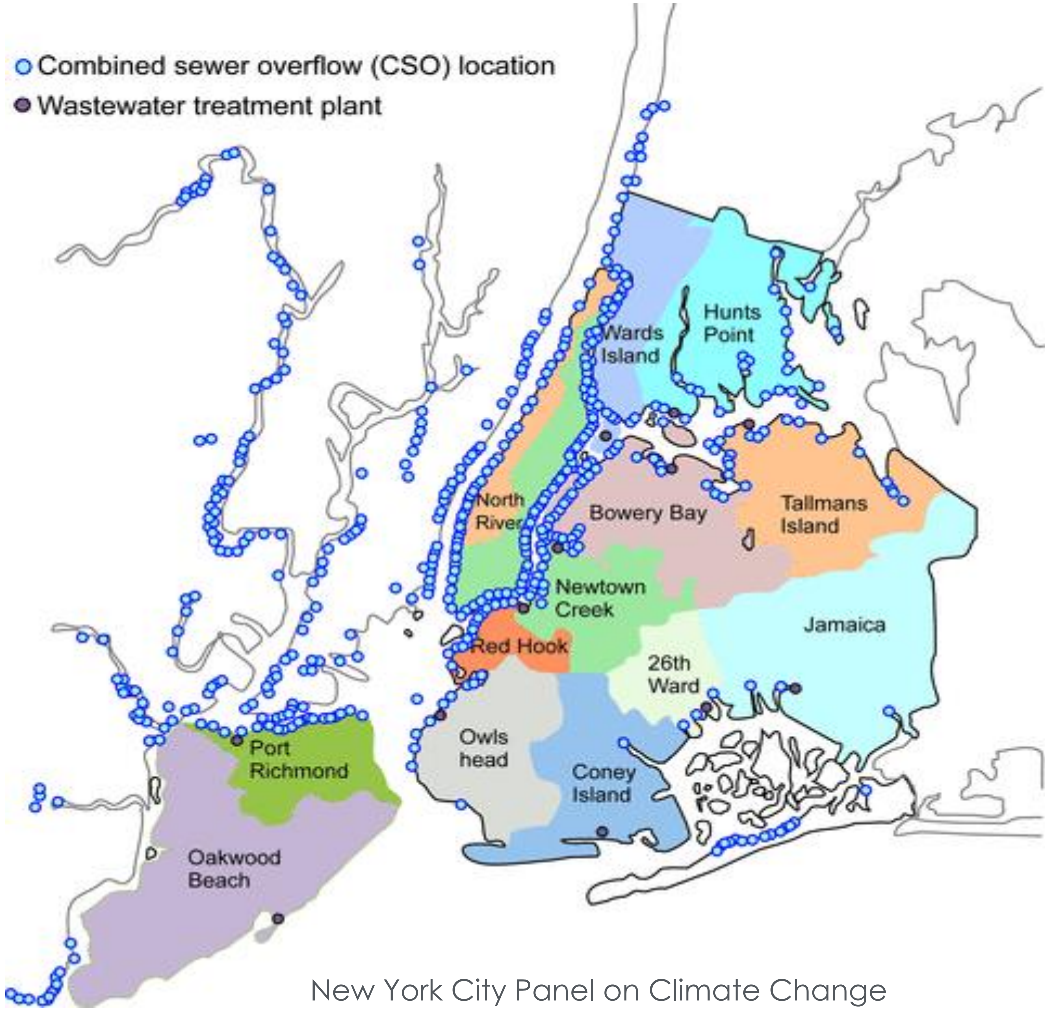
- In general, risk assessment approaches that are successful in one context are rarely able to transfer more than ~70% of approach to the next application given contextual differences.

Develop

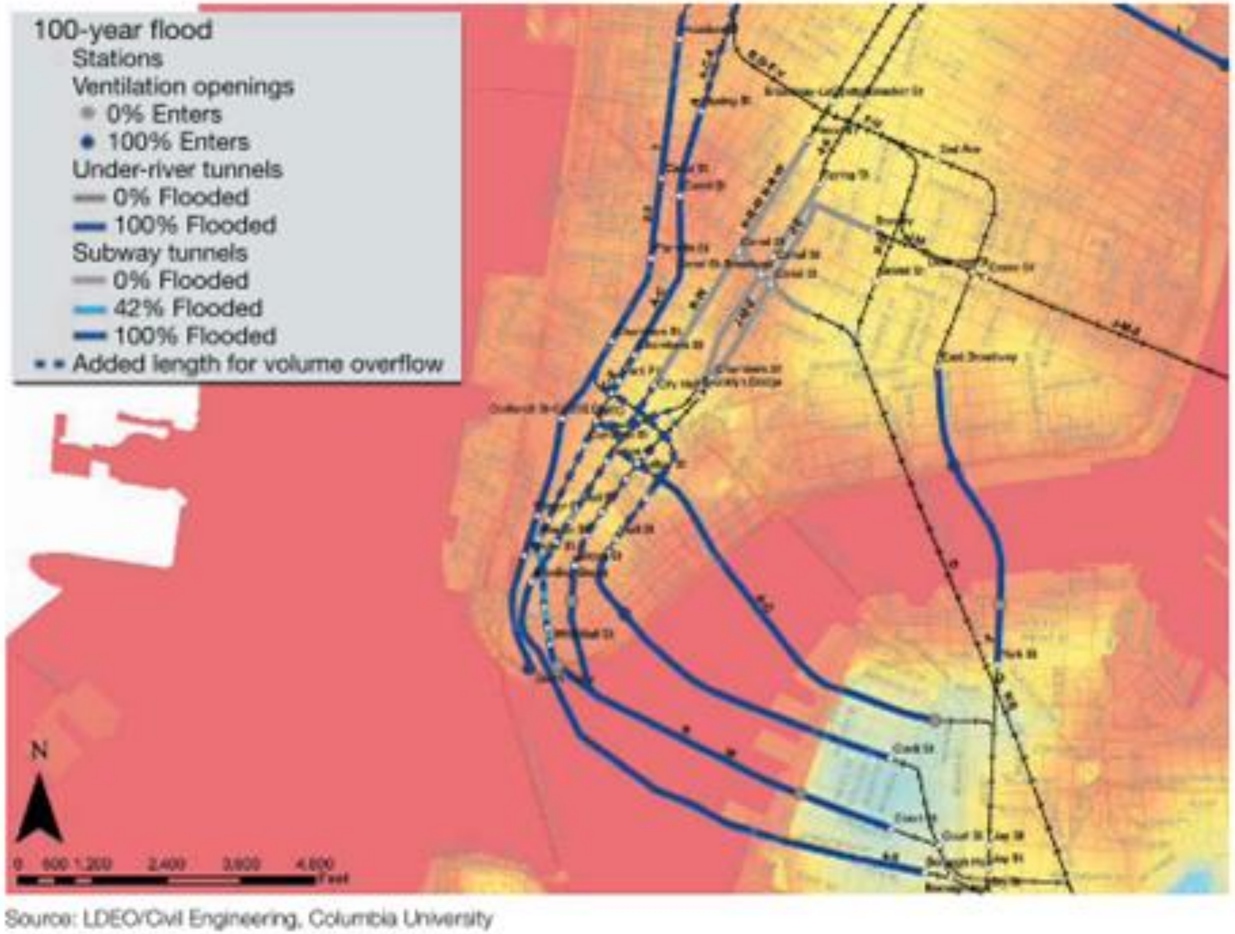
- **Agree on the process** of sustained engagement between scientists and stakeholders.
  - Manage communications plan
  - Develop familiarity and (two-way) capacity for collaboration

Unique Risks in Different Contexts

Different Decision Domains and Hazards in New York City



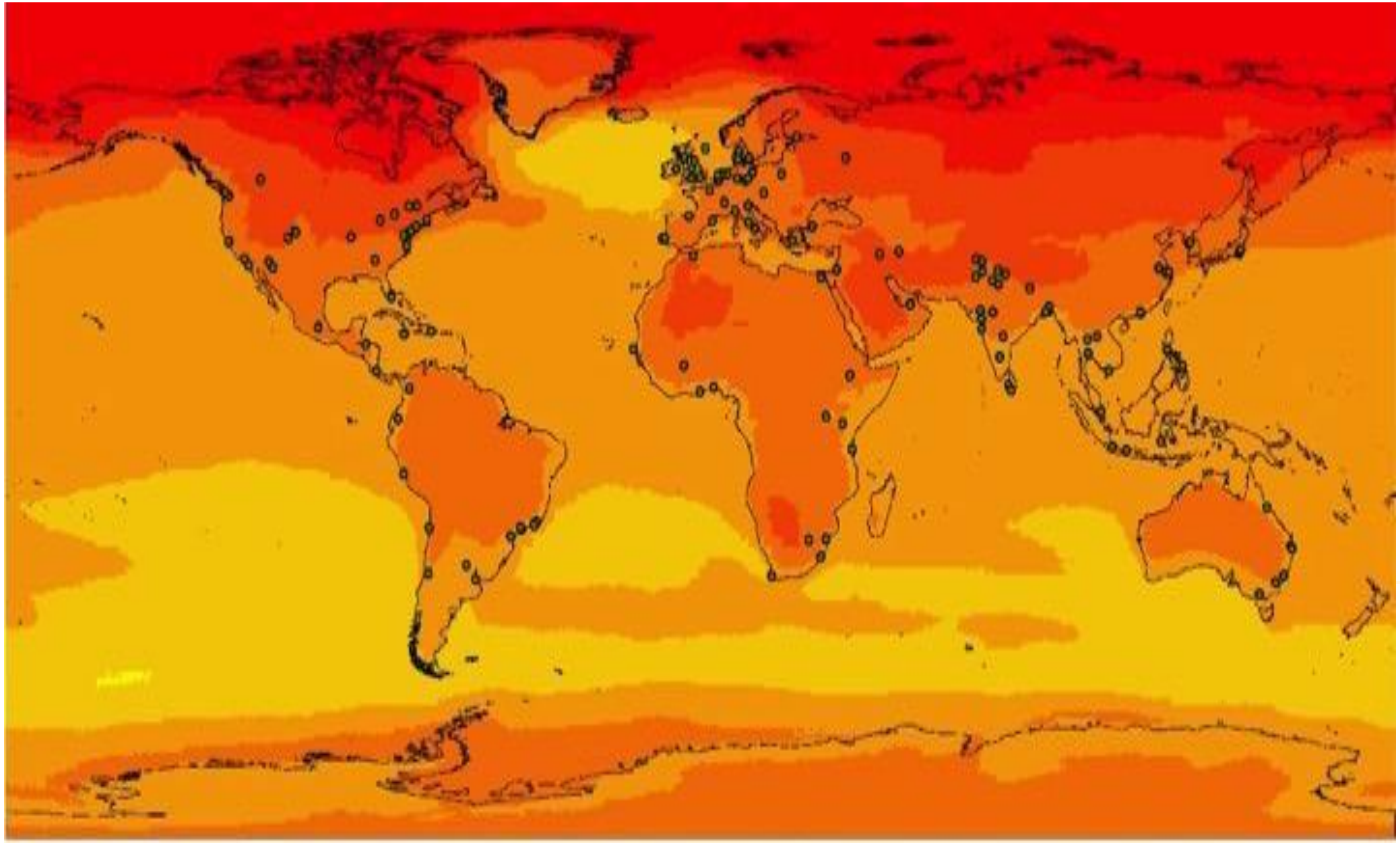
New York City Panel on Climate Change (Zimmerman et al., 2010)



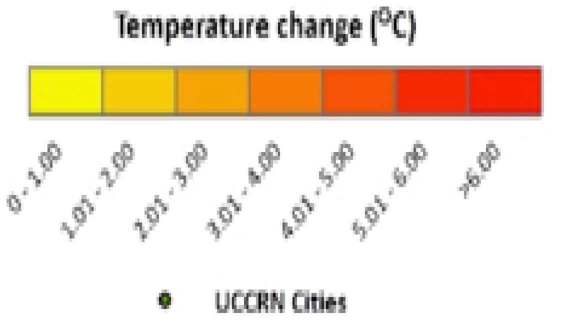
New York City Transportation System and the subway tunnels that would be inundated with 100-year Flood levels. From: Jacob et al., 2011

Unique Risks in Different Contexts

Cities have different sizes, structures, climates, and leadership

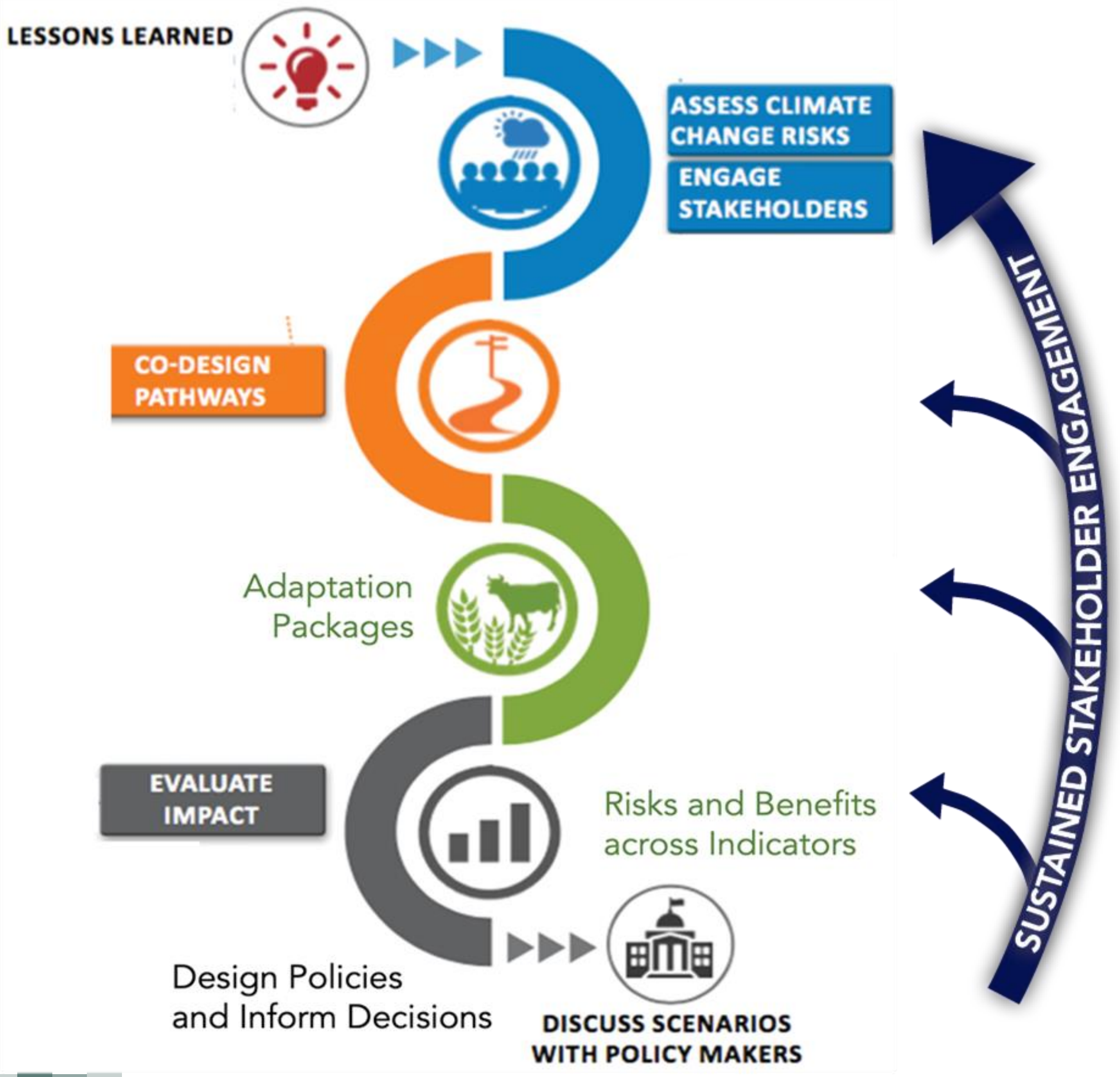


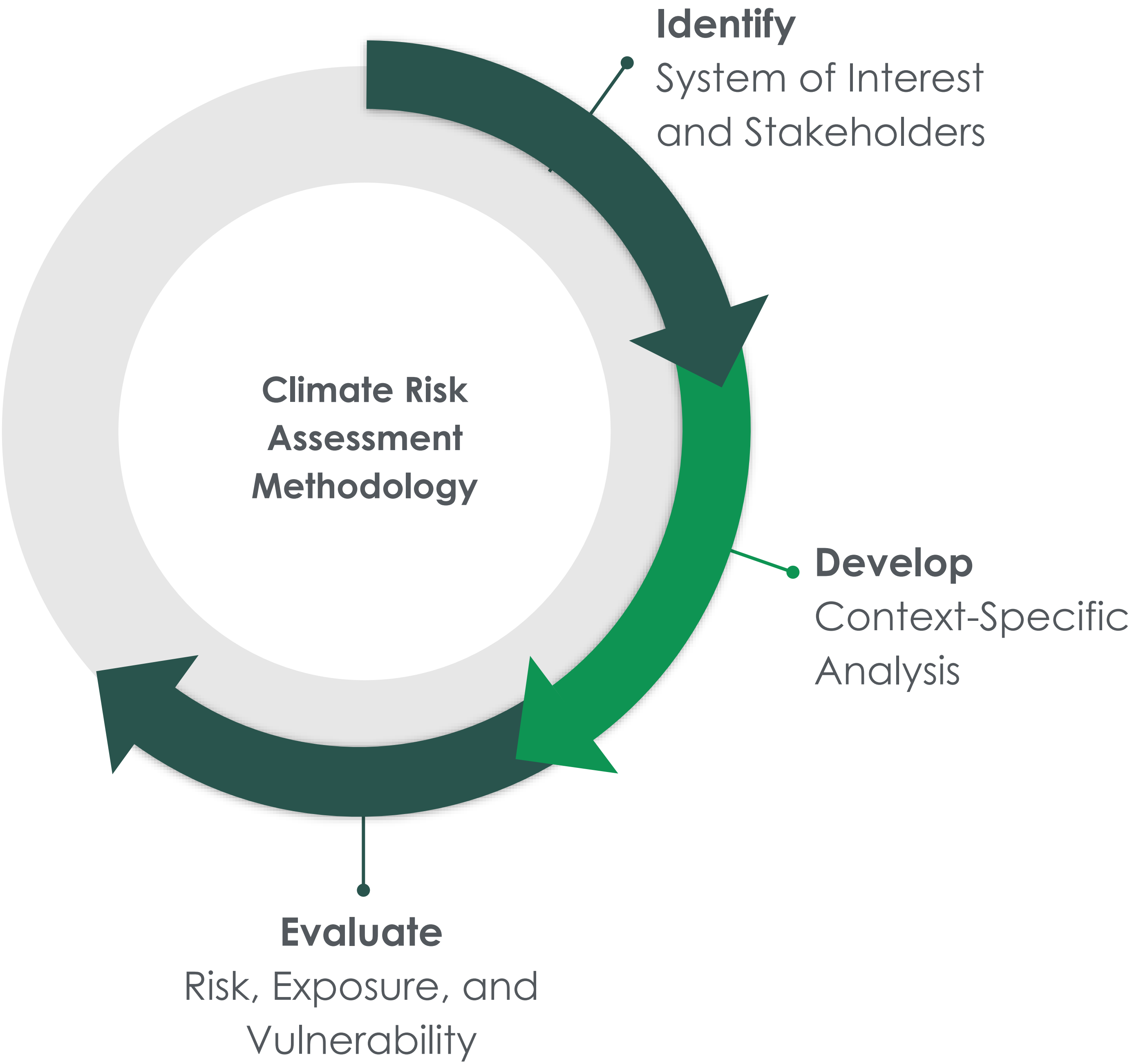
Projected Temperature Change in the 2080s, and locations of UCCRN Cities. Temperature change projection is the mean of 35 global climate models (GCMs) and two representative concentration pathways (RCP4.5 and RCP8.5). Colors represent the mean change in mean annual temperature (2070-2099 average relative to 1971-2000 average). Dots represent ARC3.2 cities. ARC3.2 Cities include Case Study Docking Station cities, UCCRN Regional Hub cities, UCCRN project cities, and cities of ARC3.2 Chapter Authors. Source: ARC3.2 (2018)



Sustained Stakeholder Engagement Plan

Utilize Expert Inputs and Build Collaborative Buy-In





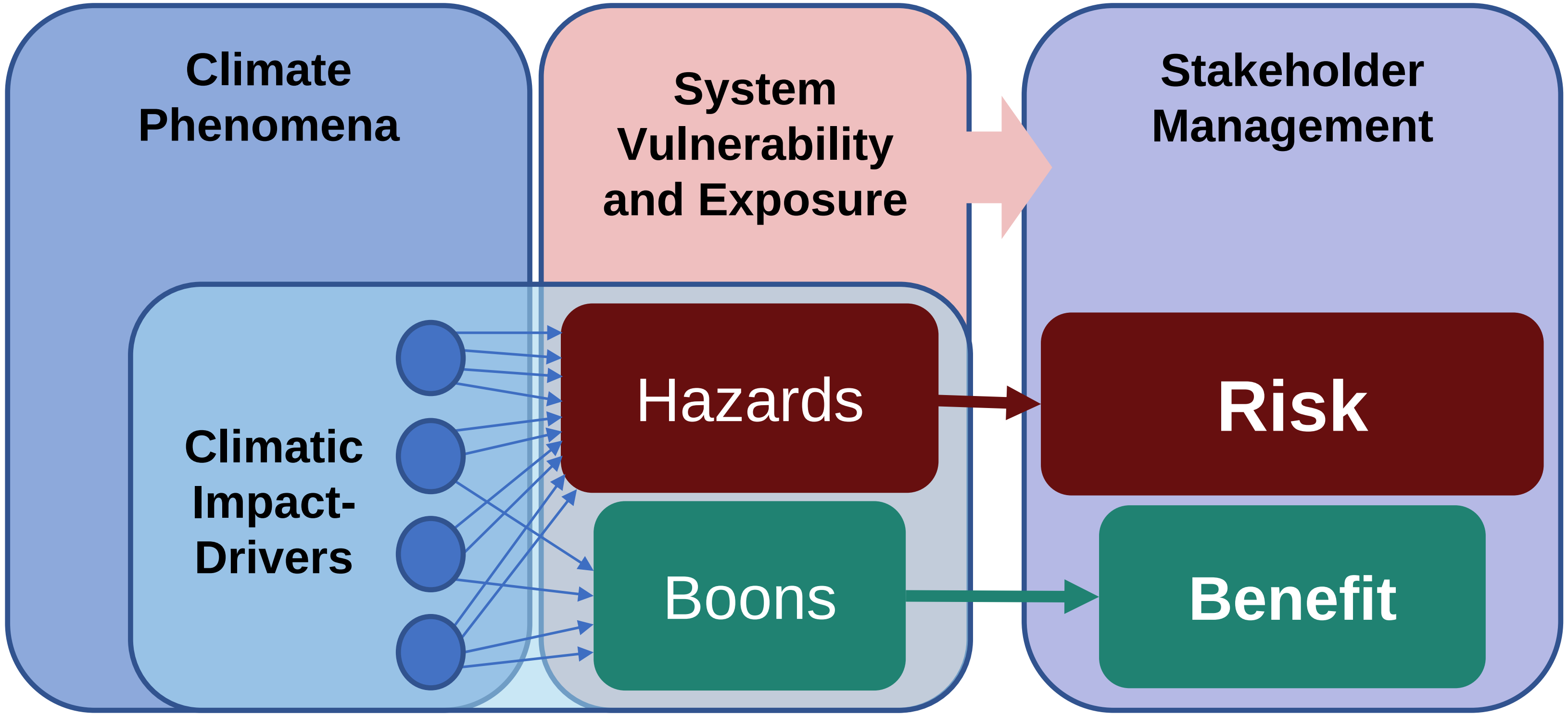
Identify
System of Interest
and Stakeholders
Climate Risk
Assessment
Methodology
Develop
Context-Specific
Analysis
Evaluate
Risk, Exposure, and
Vulnerability

Evaluate

- Interactions between hazard, vulnerability, exposure
- Potential need for a sectoral elaboration or impact model
- Determine climate information needs and select climate projection sets
- Interventions that reduce hazard, vulnerability, or exposure while avoiding additional response risk

Climatic Impact-Drivers as an Approach to Focus Climate Information

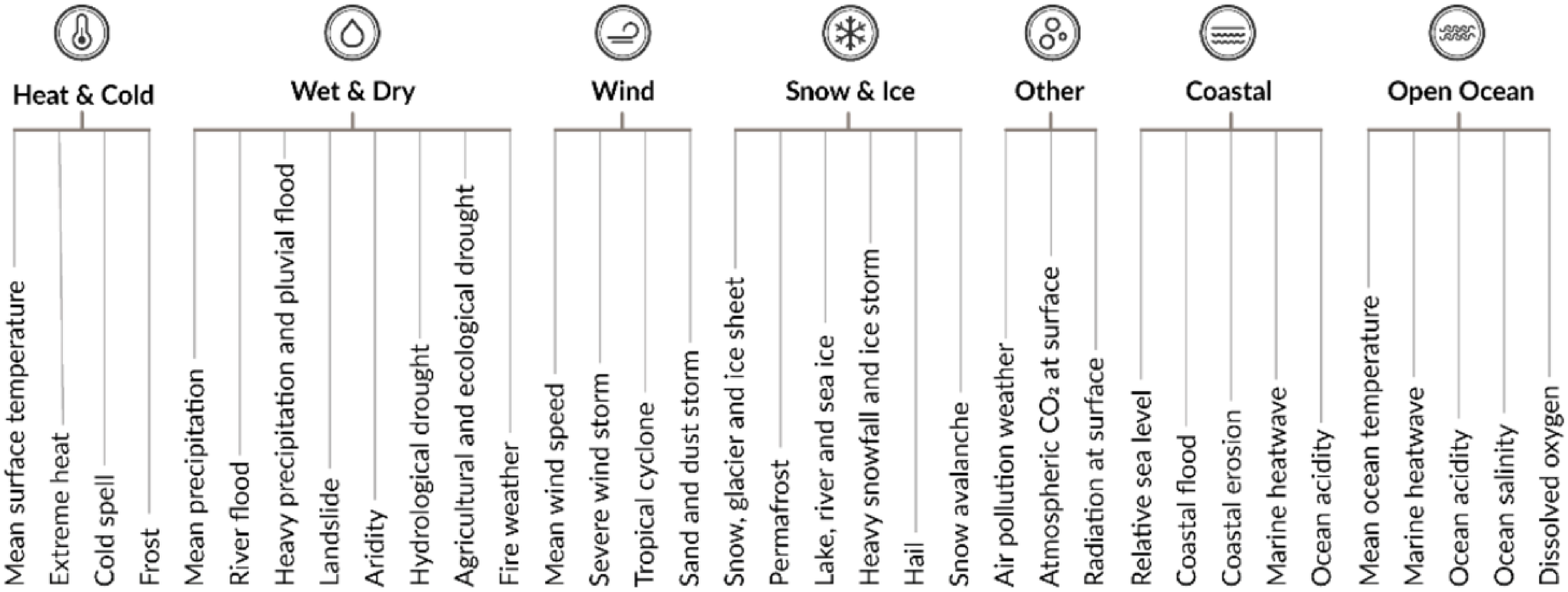
A climatic impact-driver (CID) is a climate condition that directly affects elements of society or ecosystems. Climatic impact-drivers and their changes can lead to positive, negative, or inconsequential outcomes (or a mixture).



CID Framework Paper – Ruane et al., 2022
IPCC WGI Chapter 12 – Ranasinghe et al., 2021

Climatic Impact-Drivers

Capturing Diversity of Climate Change Factors



Adopted from IPCC WGI (2021) Figure SPM.9; see also WGI Chapter 12 Ranasinghe et al. (2021); Ruane et al., 2022

Climatic Impact-Drivers

Identifying Fundamental Biophysical Responses

D R
(food system in IPCC)

Sector	Asset	Climatic Impact-driver: Heat and Cold				Wet and Dry								Wind				Snow and Ice						Coastal			Open Ocean					Other		
		Mean air temperature	Extreme heat	Cold spell	Frost	Mean precipitation	River flood	Heavy precipitation and pluvial flood	Landslide	Aridity	Hydrological drought	Agricultural and ecological drought	Fire weather	Mean wind speed	Severe wind storm	Tropical cyclone	Sand and dust storm	Snow, glacier and ice sheet	Permafrost	Lake, river and sea ice	Heavy snowfall and ice storm	Hail	Snow avalanche	Relative sea level	Coastal flood	Coastal erosion	Mean ocean temperature	Marine heatwave	Ocean acidity	Ocean salinity	Dissolved oxygen	Air pollution weather	Atmospheric CO_2 at surface	Radiation at surface
Food, Fibre and Other Ecosystem Products (WGII Chapter 5)	Crop systems	Low/moderate	High	Low/moderate	High	High	High	High	None/low	High	High	High	Low/moderate	Low/moderate	Low/moderate	Low/moderate	Low/moderate	Low/moderate	Low/moderate	None/low	Low/moderate	High	None/low	None/low	Low/moderate	None/low	None/low	None/low	None/low	None/low	None/low	Low/moderate	High	Low/moderate
	Livestock and pasture systems	Low/moderate	High	High	None/low	Low/moderate	High	Low/moderate	None/low	High	Low/moderate	High	Low/moderate	None/low	Low/moderate	None/low	Low/moderate	Low/moderate	None/low	None/low	Low/moderate	Low/moderate	None/low	None/low	Low/moderate	None/low	None/low	None/low	None/low	None/low	None/low	Low/moderate	Low/moderate	Low/moderate
	Forestry systems	High	High	Low/moderate	Low/moderate	Low/moderate	Low/moderate	None/low	None/low	High	None/low	High	High	Low/moderate	Low/moderate	None/low	None/low	Low/moderate	Low/moderate	None/low	Low/moderate	Low/moderate	None/low	None/low	Low/moderate	None/low	None/low	None/low	None/low	None/low	None/low	Low/moderate	High	Low/moderate
	Fisheries and aquaculture systems	Low/moderate	Low/moderate	None/low	None/low	None/low	Low/moderate	None/low	None/low	None/low	Low/moderate	None/low	None/low	Low/moderate	Low/moderate	Low/moderate	None/low	Low/moderate	None/low	Low/moderate	None/low	None/low	None/low	Low/moderate	High	None/low	High	High	High	Low/moderate	Low/moderate	None/low	None/low	None/low

None/low confidence | Low/moderate | High

Impacts and risk relevance

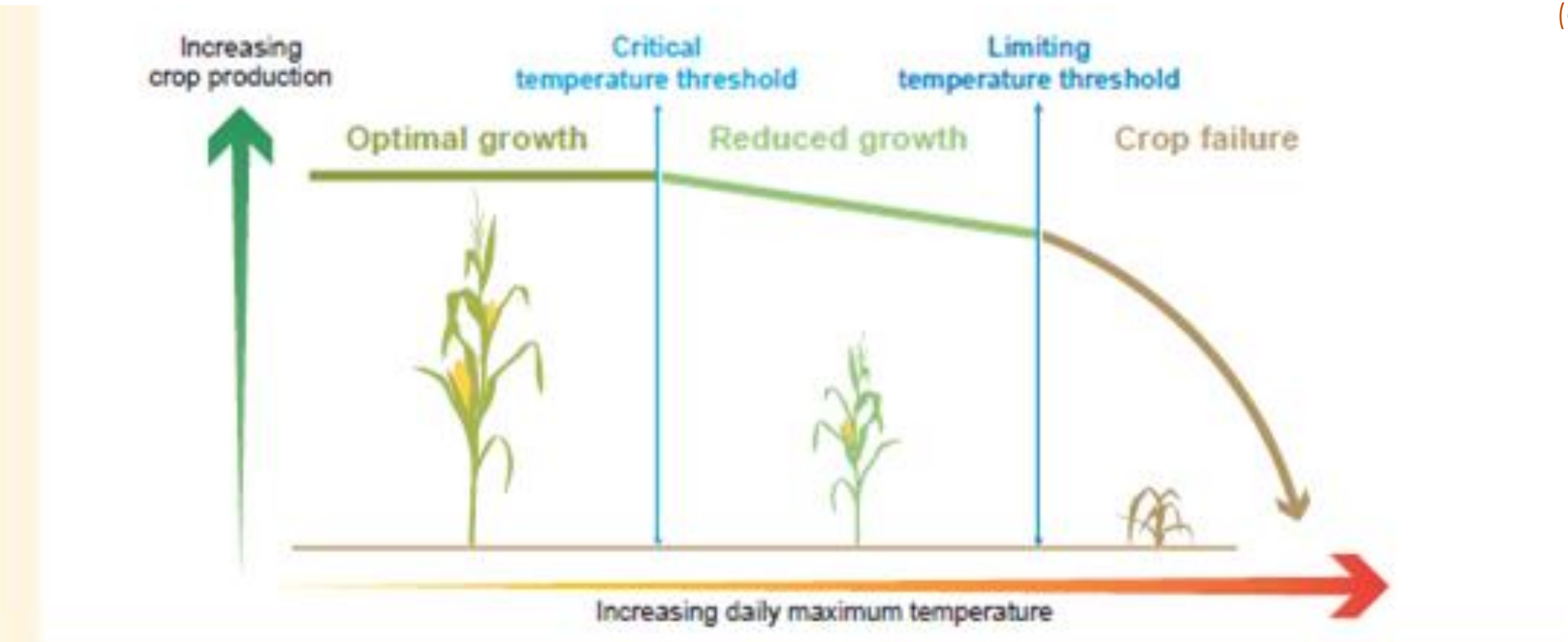
IPCC AR6 WGI Table 12.2, Ranasinghe et al., 2021

Similar table rows for many other sectors

Climatic Impact-Drivers

Translating Responses into Context-Specific Hazard Metrics Linked with Vulnerability

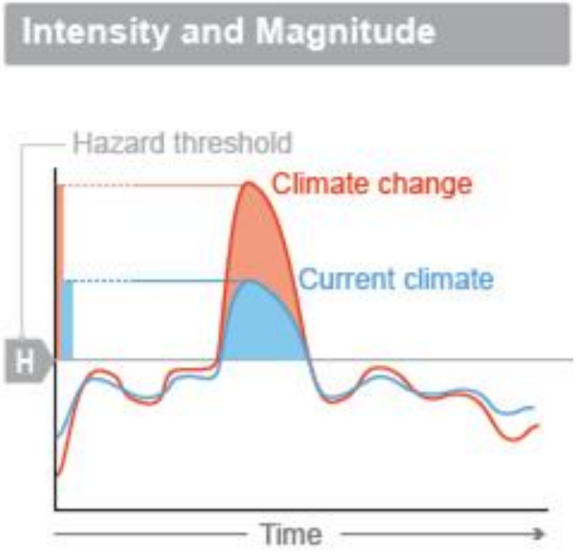
(e.g., for crops)



FAQ 12.2, Figure 1 | Crop response to maximum temperature thresholds. Crop growth rate responds to daily maximum temperature increases, leading to reduced growth and crop failure as temperatures exceed critical and limiting temperature thresholds, respectively. Note that changes in other environmental factors (such as carbon dioxide and water) may increase the tolerance of plants to increasing temperatures.

Climatic Impact-Drivers

Metrics Help Identify Standout Characteristics of Climate Change



Climate change can alter the **intensity and magnitude**, **frequency**, **duration**, **timing**, and **spatial extent** of a region's climate hazards.

Challenge:

- Determining the context-specific response thresholds, suitability bounds, and operational ranges for human and natural systems.

Adopted from IPCC WGI (2021) FAQ 12.3; See also WGI Chapter 12, Ranasinghe et al. (2021); Ruane et al. (2022)

Information Resources for Geohazards

Great Introductions in Other ARSET Trainings

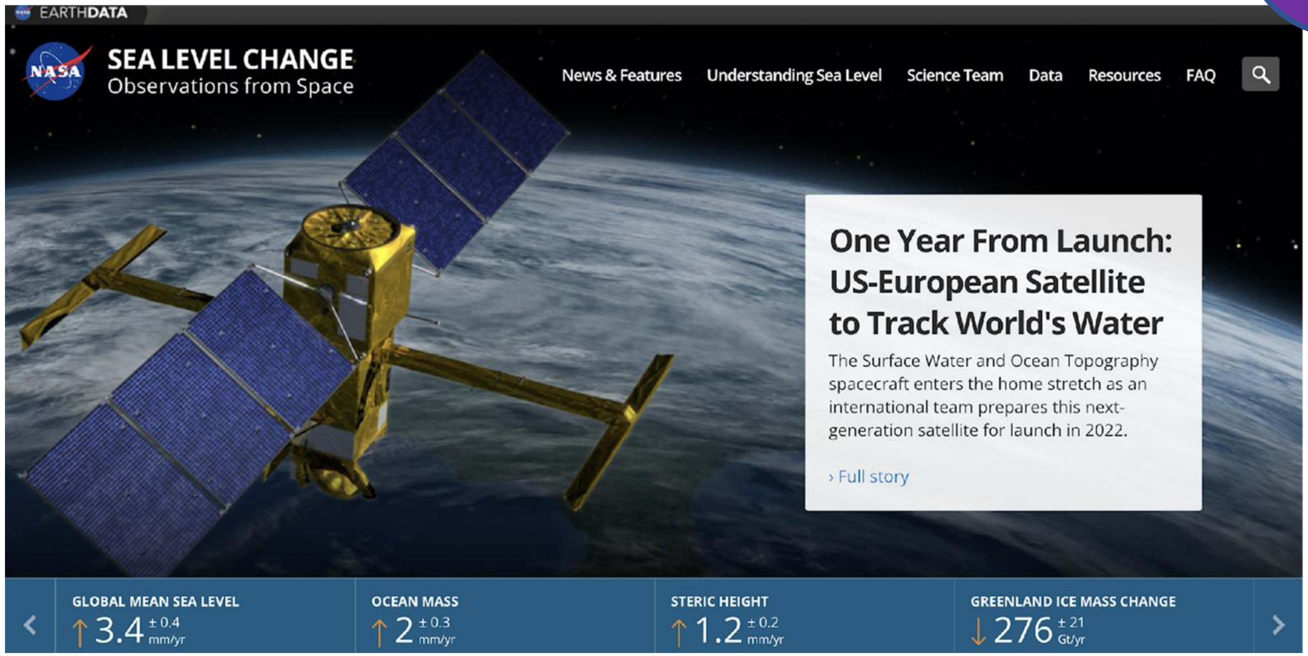
Remote Sensing Resources:

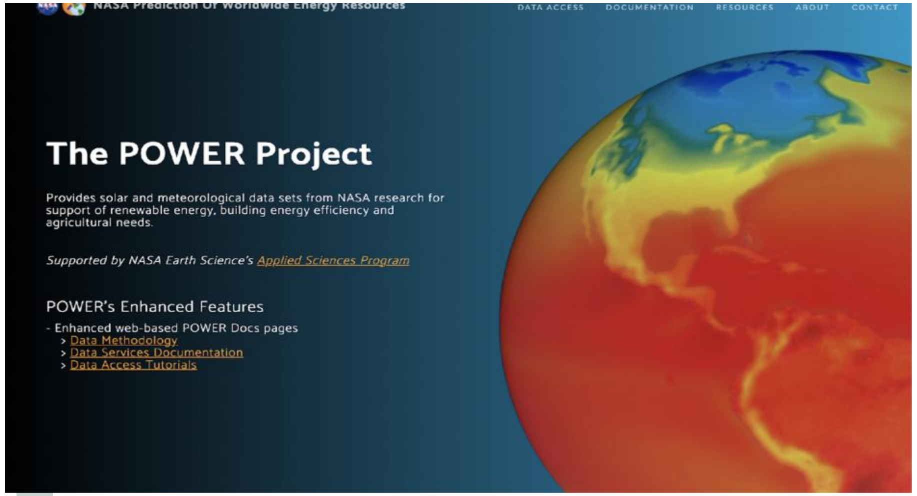
- Weather Products (e.g., IMERG, MODIS Land-Surface Temperature)
- Visible Imagery (e.g., LANDSAT, ESA Sentinel)
- Biosphere and Fire Imagery (e.g., MODIS NDVI, FIRMS)
- Water Budget Products (e.g., OpenET, SMAP, Sentinel-1 Synthetic Aperture Radar)

Models and Projection Tools:

- Weather and Land Hydrology Retrospective Analyses (e.g., MERRA-2; LIS)
- Climate Projections (e.g., GISS Model-E, NEX GDDP)
- Coastal Hazard Projections (e.g., NASA Sea Level Rise Tool)

NASA Geoinformation Resources





Selecting a Climate Projection Set

Based on Local Responses and Evaluated Needs

- **Select based upon mitigation, adaptation, and risk applications contexts.**

- **Key Characteristics of a Climate Projection Set (see 2022 ARSET Training):**
  1. Global Climate Models
  2. Scenarios and Storylines
  3. Downscaling (dynamical, statistical)
  4. Temporal Resolution
  5. Spatial Resolution
  6. Post-Processing (e.g., bias-adjustment)
  7. 'Applications-Ready' Variables Needed to Evaluate Local Risk

Tuesday, September 20, 2022

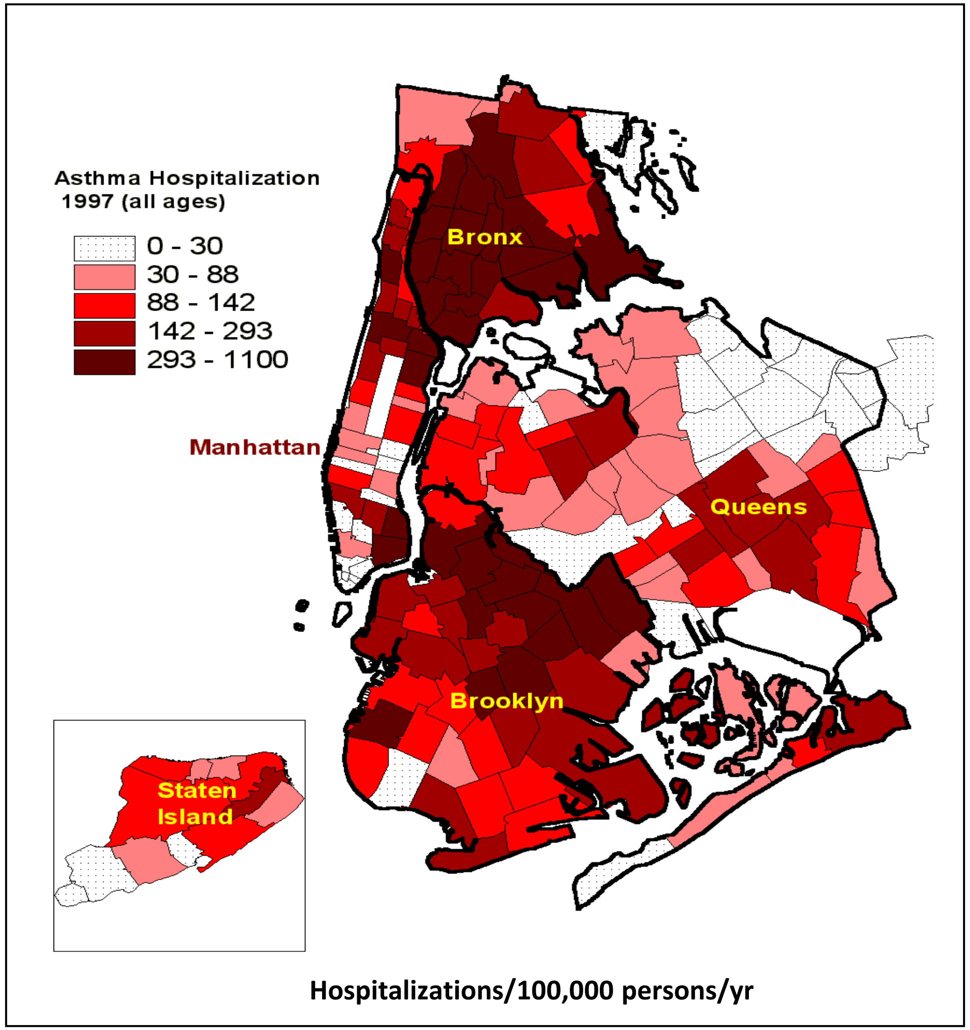
Speakers: Alex Ruane & Meridel Phillips

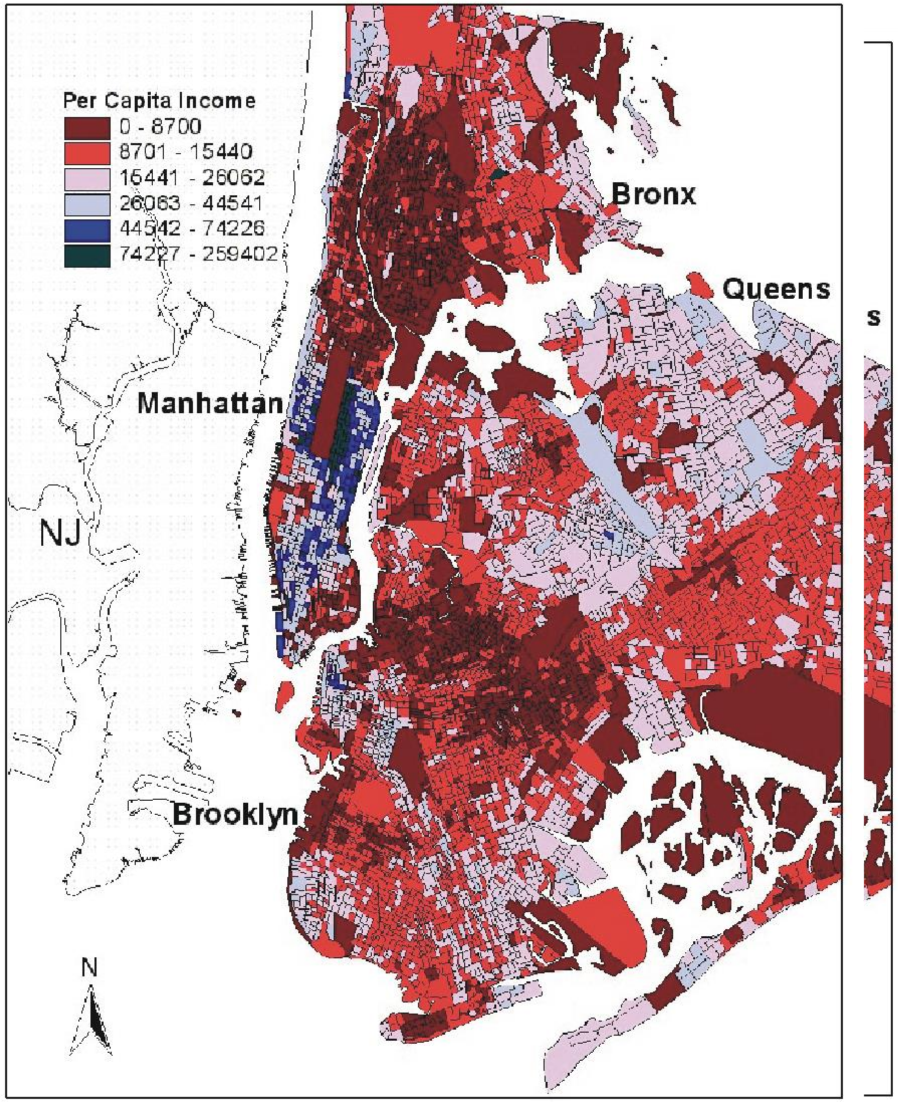
- **More complex projection sets are not necessarily better.**
  - Resource constraints
  - Illusion of high levels of detail

Vulnerability

Respiratory Health in New York City

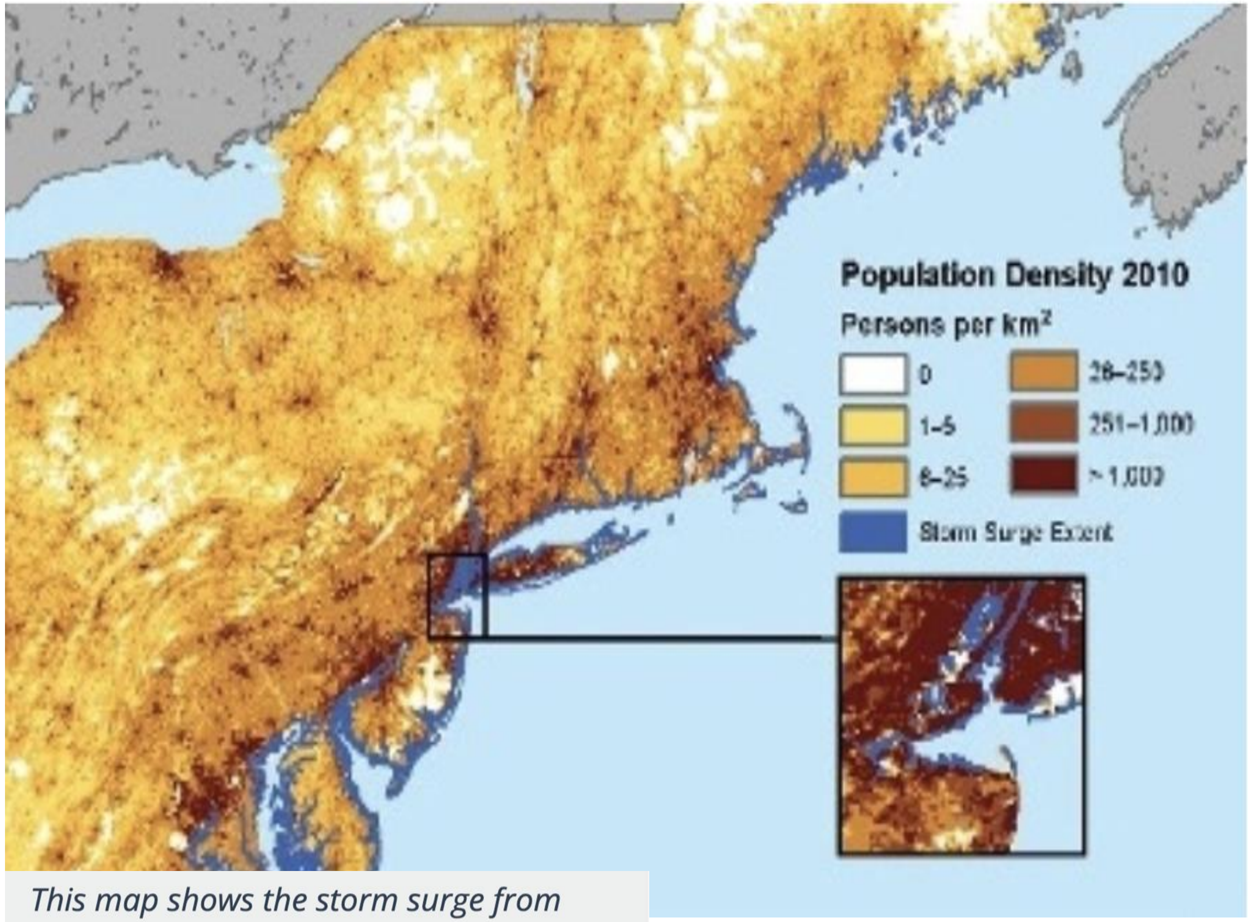
Asthma Hospitalizations, 1997 –All Ages





Geoinformation Resources
Vulnerability and Exposure

- Socioeconomic Data (e.g., SEDAC)
- Land Use / Land Cover Products (e.g., Cropland Data Layer)
- Topography (e.g., ASTER DEM)
- GIS datasets may be curated by local agencies (e.g., NYC Open Data).



This map shows the storm surge from Hurricane Sandy in October 2012, as estimated by the Federal Emergency Management Agency, coupled with SEDAC population density data for 2010.

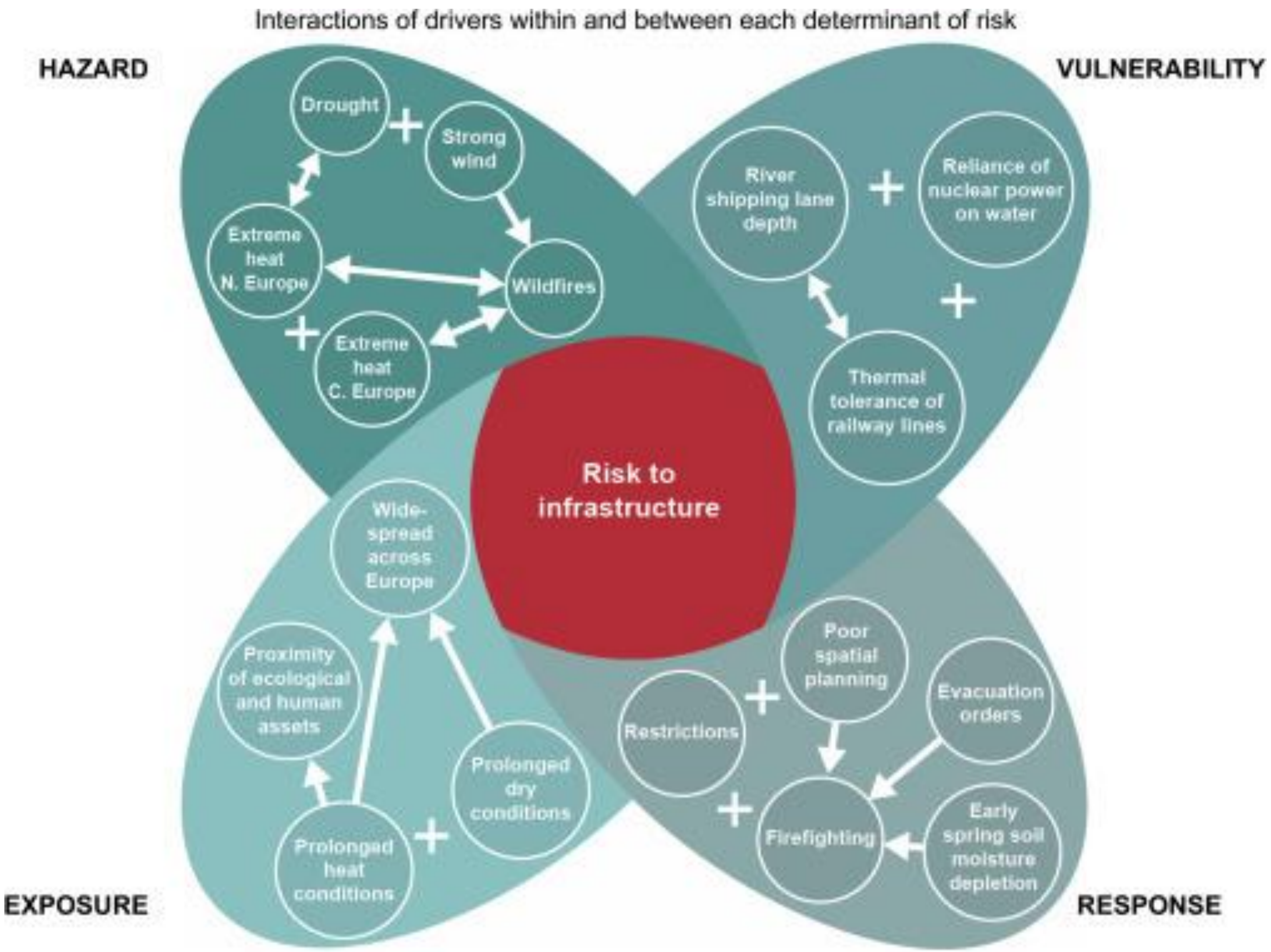
Evaluate

Wet Hazards Pathways to Impact in New York City

	Communication Infrastructure Implications	Energy Infrastructure Implications
Precipitation, Intense Precipitation & Droughts	**Increased average annual precipitation could:** • place strain on equipment and machinery, increasing the need for maintenance and reducing lifetimes	• improve potential for hydropower • lead to more Combined Sewer Overflow (CSO) events, polluting coastal waterways and reducing ability of power plants to discharge water into sewers • increase turbidity in reservoirs affecting costs associated with cleaning water for cooling • place strain on equipment and machinery, increasing the need for maintenance and reduce lifetimes
	More frequent and intense drought could: • place strain on equipment and machinery, increasing need for maintenance and reducing lifetimes	
	More frequent intense rainfall could: • lead to more flooding of underground cables, equipment and fuel tanks • result in a possible collapse of conduits • decrease accessibility to underground infrastructure for repairs	• lead to more street, basement and sewer flooding which will overload drainage systems, resulting in increased wear and tear on equipment and infrastructure

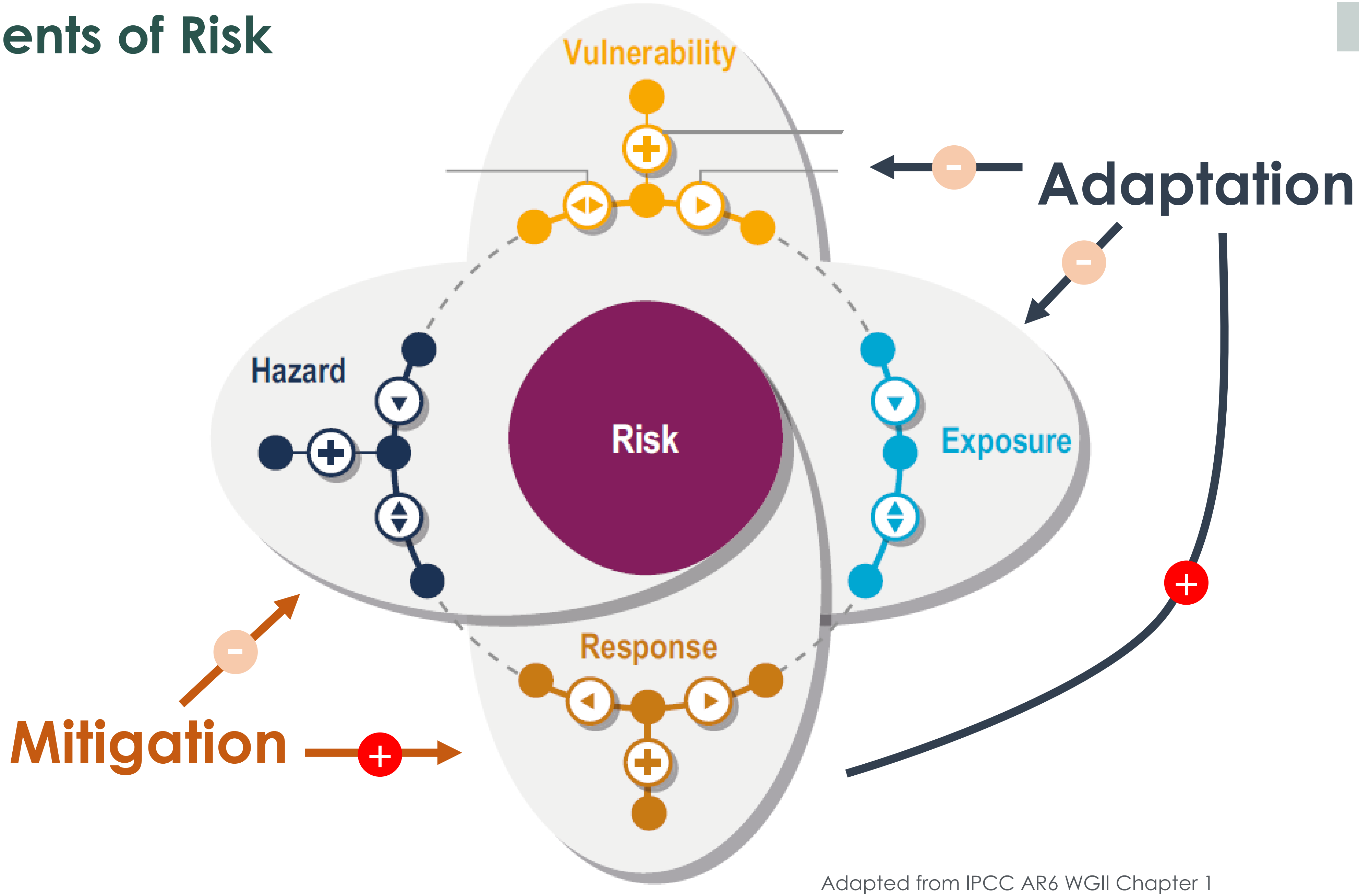
New York City Panel on Climate Change – Climate Risk Information; 2009

Risk to Infrastructure

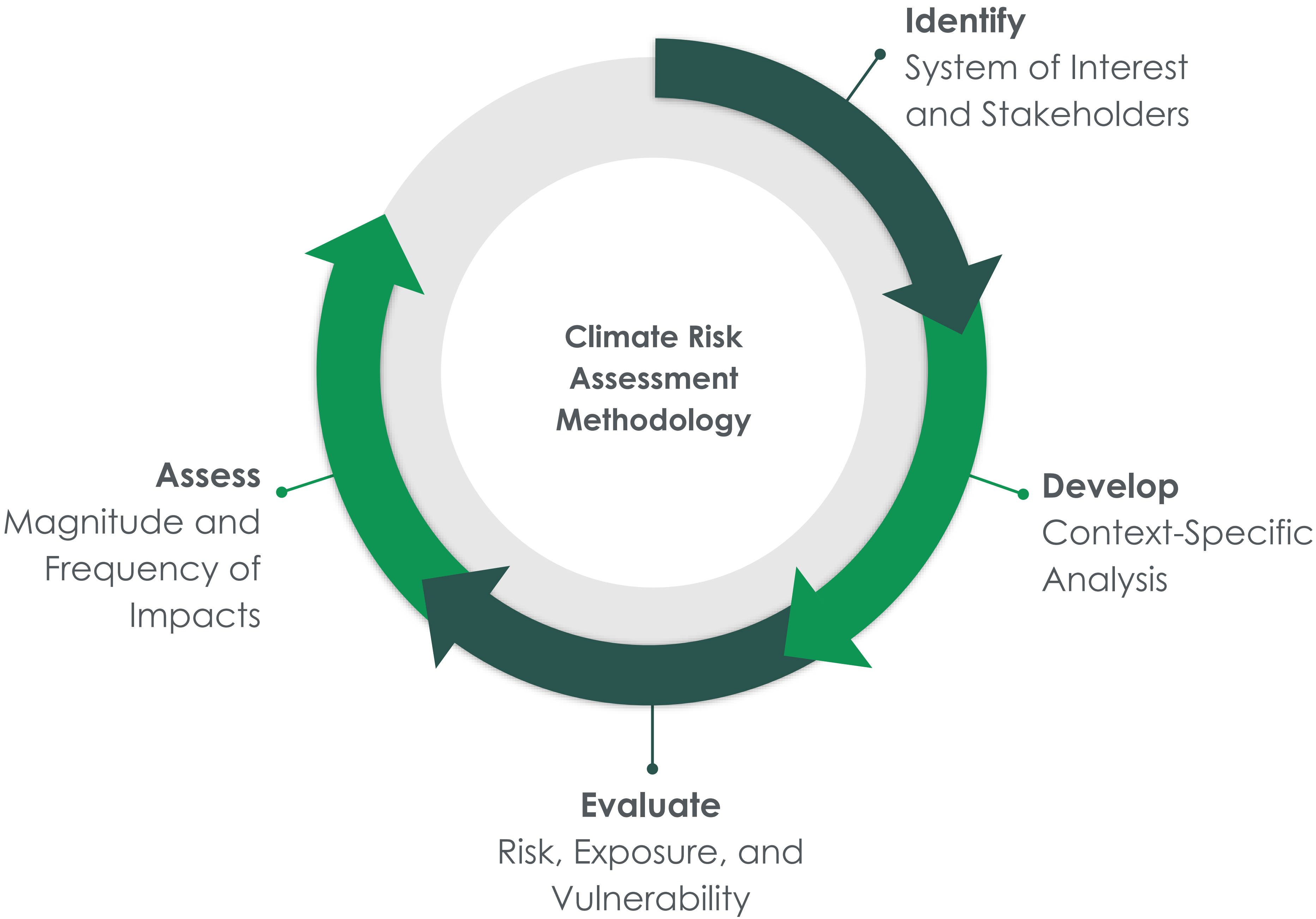


Source: Simpson et al 2021, A framework for complex climate change risk assessment, One Earth, Volume 4, Issue 4

Components of Risk



Adapted from IPCC AR6 WGII Chapter 1
Figure 1.5c; Begum et al., 2022


Identify
System of Interest and Stakeholders
Develop
Context-Specific Analysis
Evaluate
Risk, Exposure, and Vulnerability
Assess
Magnitude and Frequency of Impacts
Climate Risk Assessment Methodology

Assess

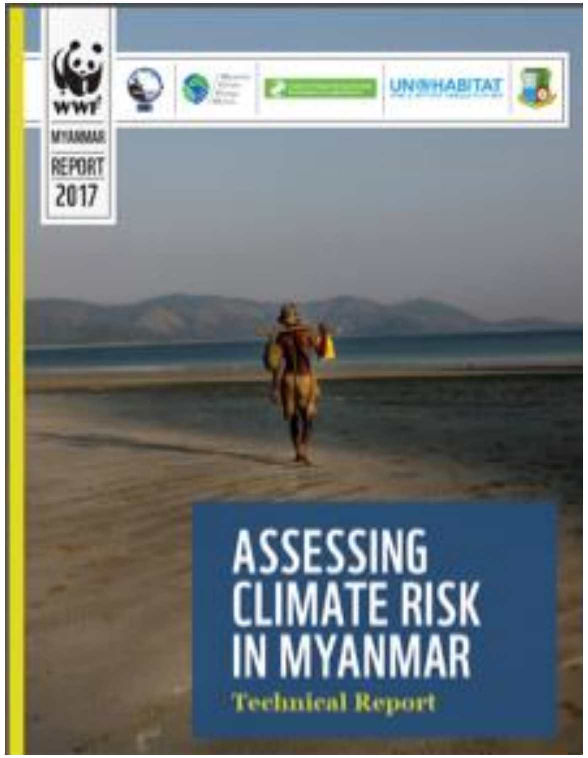
- Changes in Hazards (magnitude, frequency, duration, timing, spatial extent)
- Trends in Vulnerability and Exposure (scenarios and pathways)
- Risks With and Without Adaptation
- Benefit of Implementing Adaptation Options

Assess

Example from World Wildlife Fund (WWF) Assessment in Myanmar

Projected Frequency of Occurrence of Historical, Daily, 95th Percentile Temperatures in April for Inland Regions in Myanmar

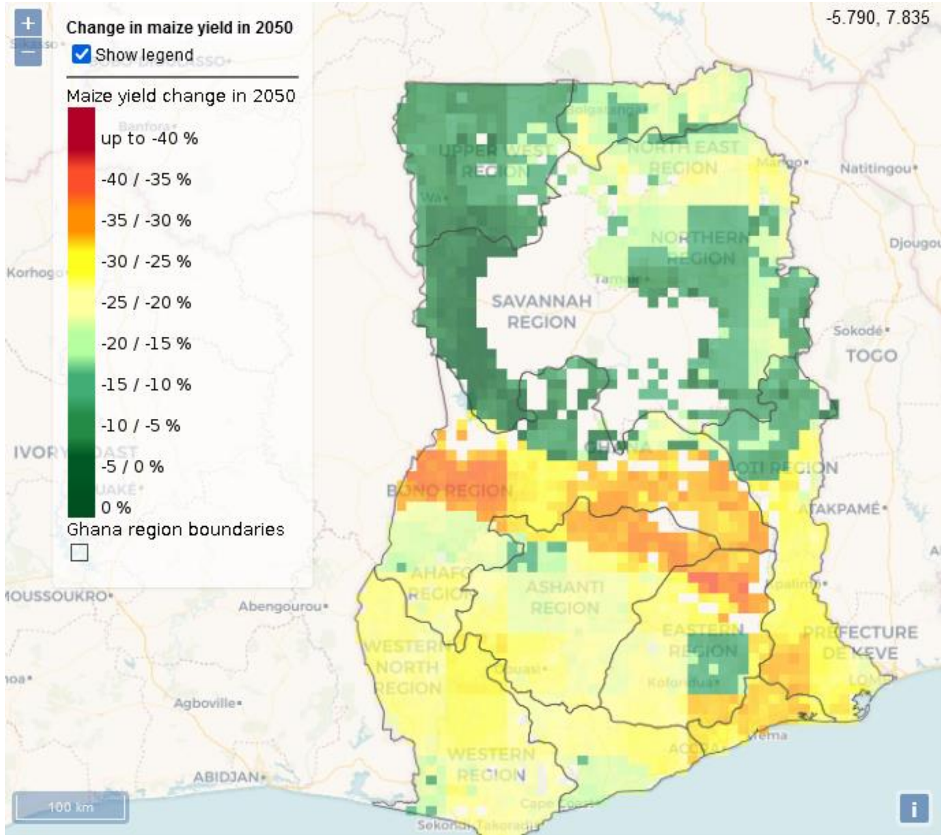
21 GCMs, RCP 4.5 and 8.5, NASA NEX-GDDP data (CMIP5)
Columbia University with World Wildlife Foundation (WWF) – ADVANCE Project



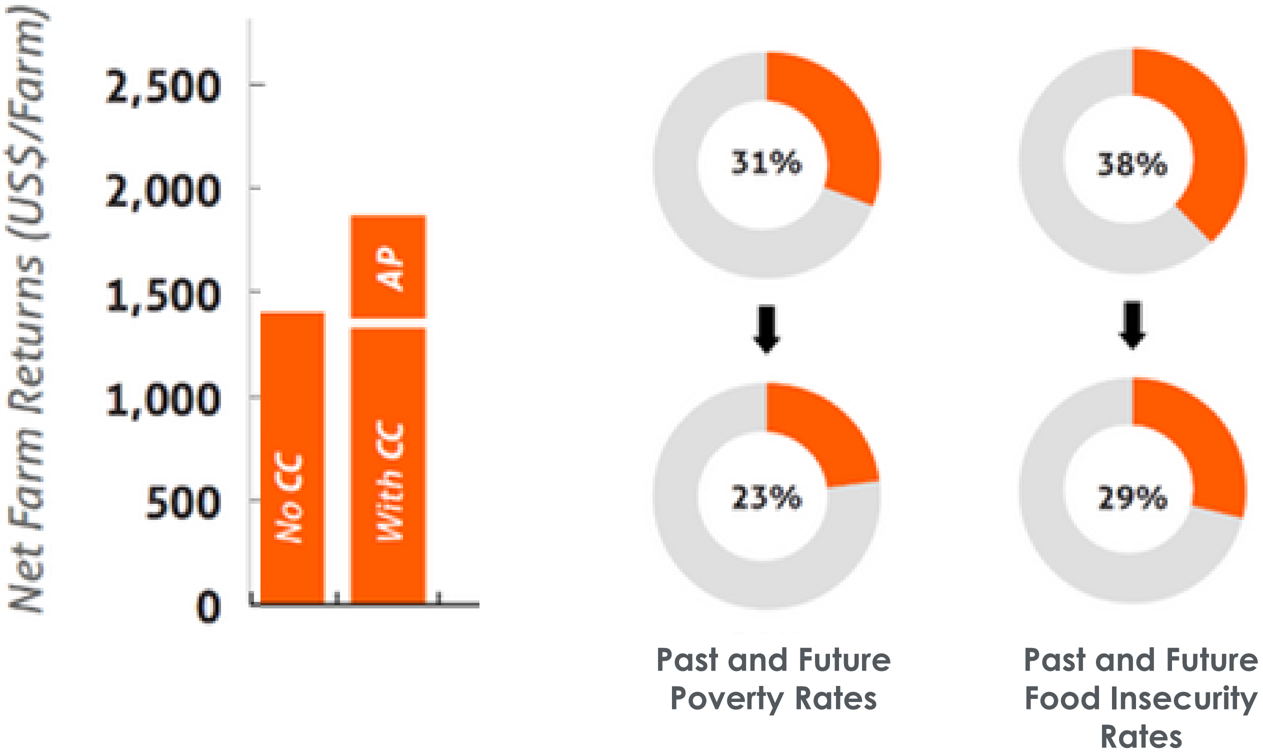
Horton et al., 2016

Assess

Example from AgMIP Regional Integrated Assessment in Ghana



(Left) Maize Yield Impacts in Ghana

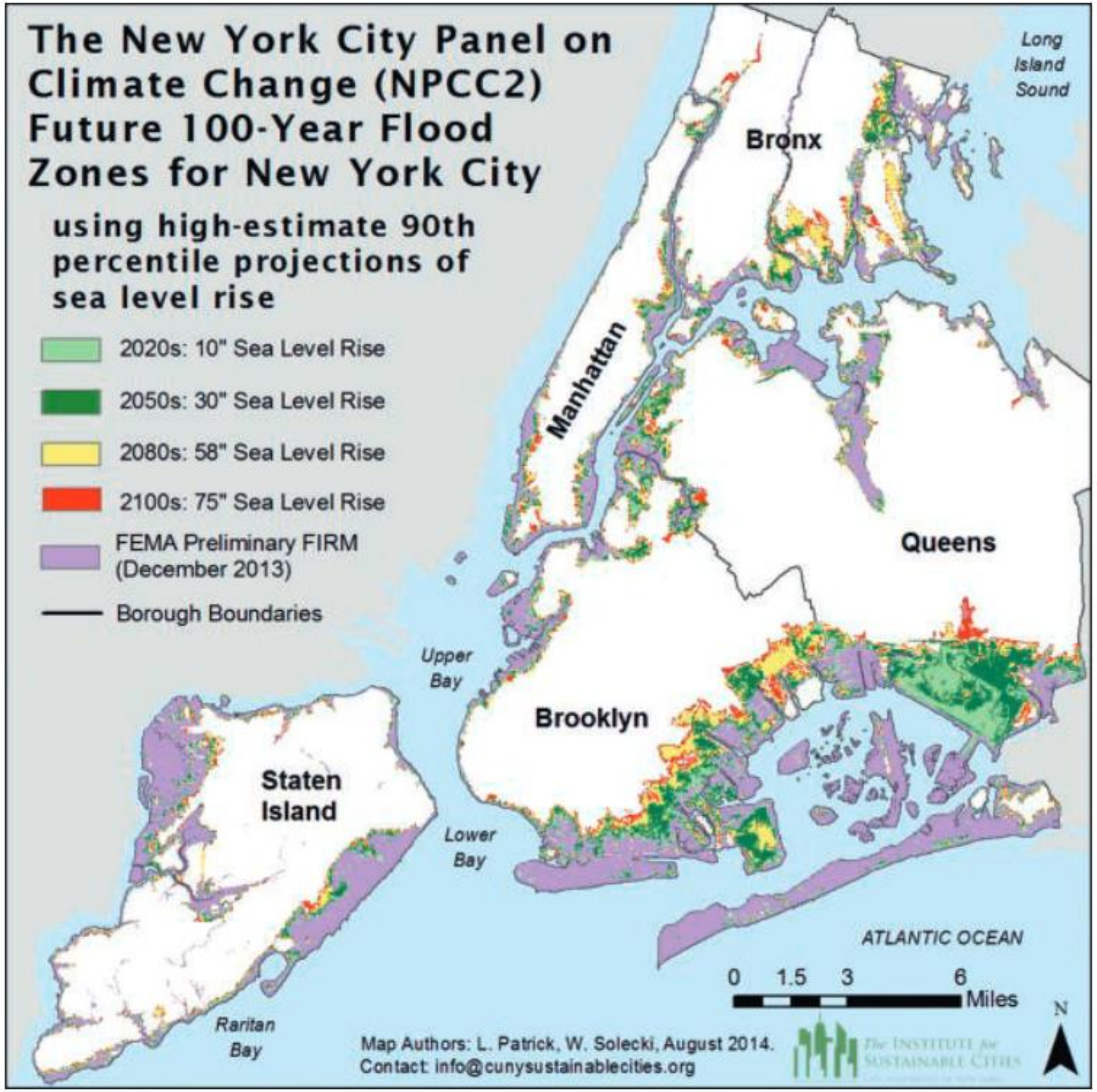


(Right) Projected future economic outcomes with and without climate change (high emissions, 2050) and adaptation package featuring heat-tolerant seed varieties. Simulations utilize DSSAT crop model and TOA-MD Household Economic Model

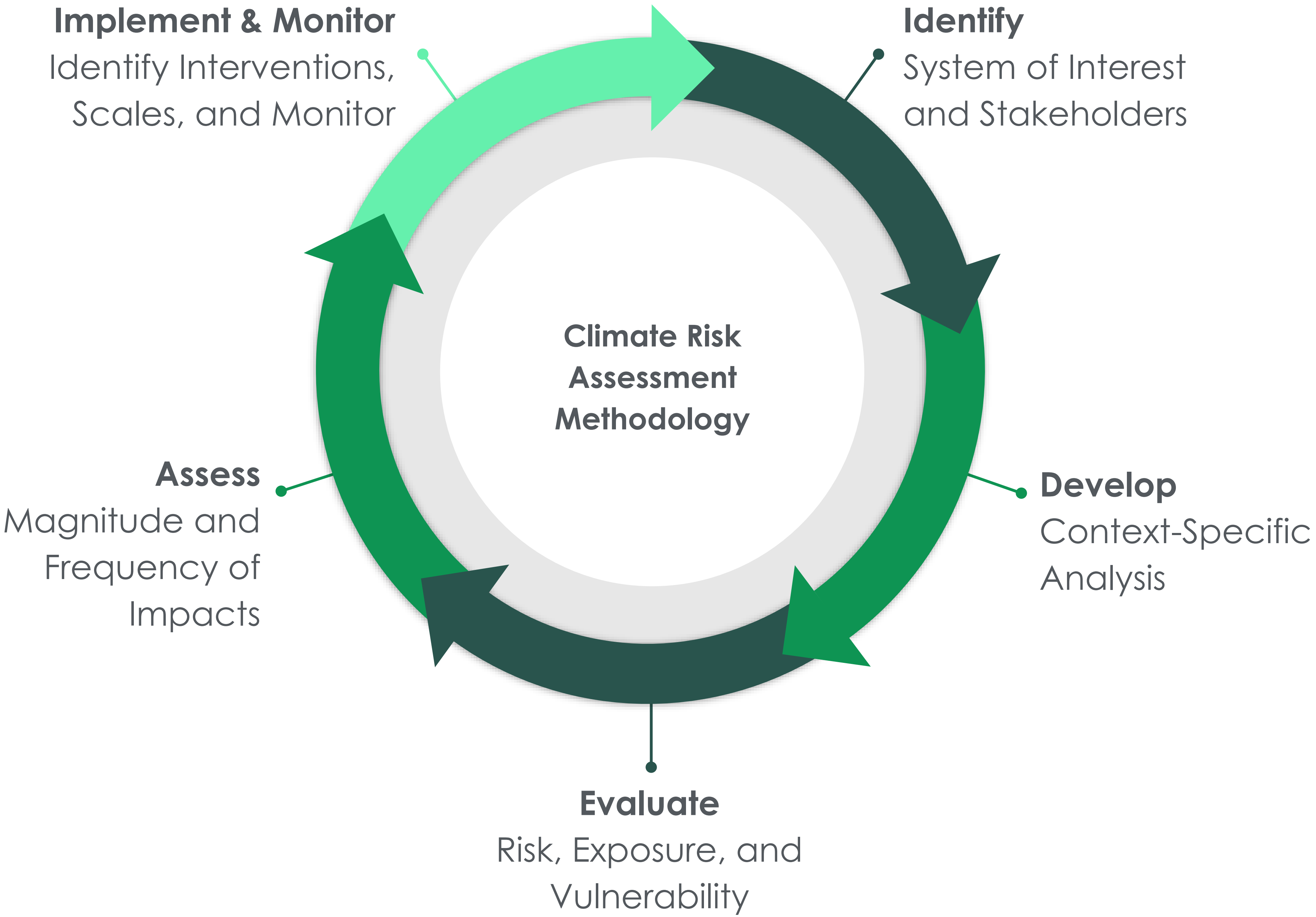
Dilys McCarthy et al.; adapted from: https://agmipimpactsexplorer.wenr.wur.nl/ghana-national-study

Assess

Coastal Flooding Risk in New York City



New York Panel on Climate Change, 2015


Climate Risk Assessment Methodology
Identify
System of Interest and Stakeholders
Develop
Context-Specific Analysis
Evaluate
Risk, Exposure, and Vulnerability
Assess
Magnitude and Frequency of Impacts
Implement & Monitor
Identify Interventions, Scales, and Monitor

Implement and Monitor

Flexible Adaptation Pathways to Manage Risk

- Identify affected scales and systems
- Connect risks to decision processes and available resources
- Prioritize interventions and acceptable level of risk
- Implement adaptations with stated design criteria (e.g., cost, protection levels, lifespan)
- Monitor performance against design criteria
- Reassess given non-stationary climate conditions and shifting levels of acceptable risk

Implement and Monitor

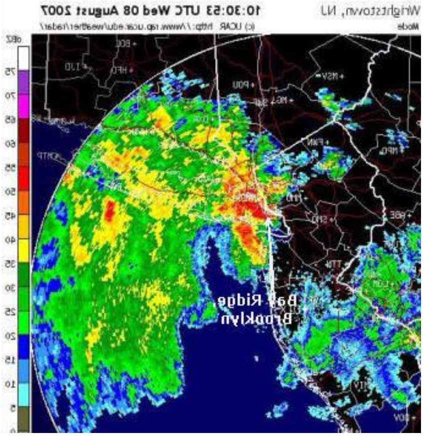
- Adaptations need to have a hazard that they are targeting.
- Higher sea walls help protect against coastal flooding, but do not alleviate extreme heat conditions.
  - If intervention is not linked to a hazard, it may not be a climate adaptation.
  - Adapting to one climate hazard does not solve other climate risks.
  - Adaptation packages are important.
- The goal is to create synergies and co-benefits between adaptation, mitigation, and other center priorities.

Implement and Monitor

Identifying Adaptations that Protect Against Flooding in New York

Rainwater Drainage

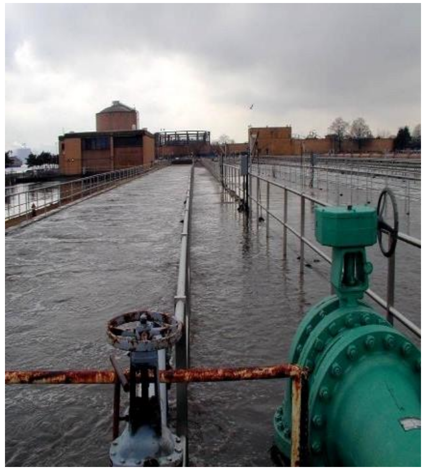
- Improve collection (expand sewers and pumps and retain stormwater above ground)
- Enhance natural landscape and drainage
- Plan for controlled flooding



August 8, 2007

Storm Surge & Water Treatment

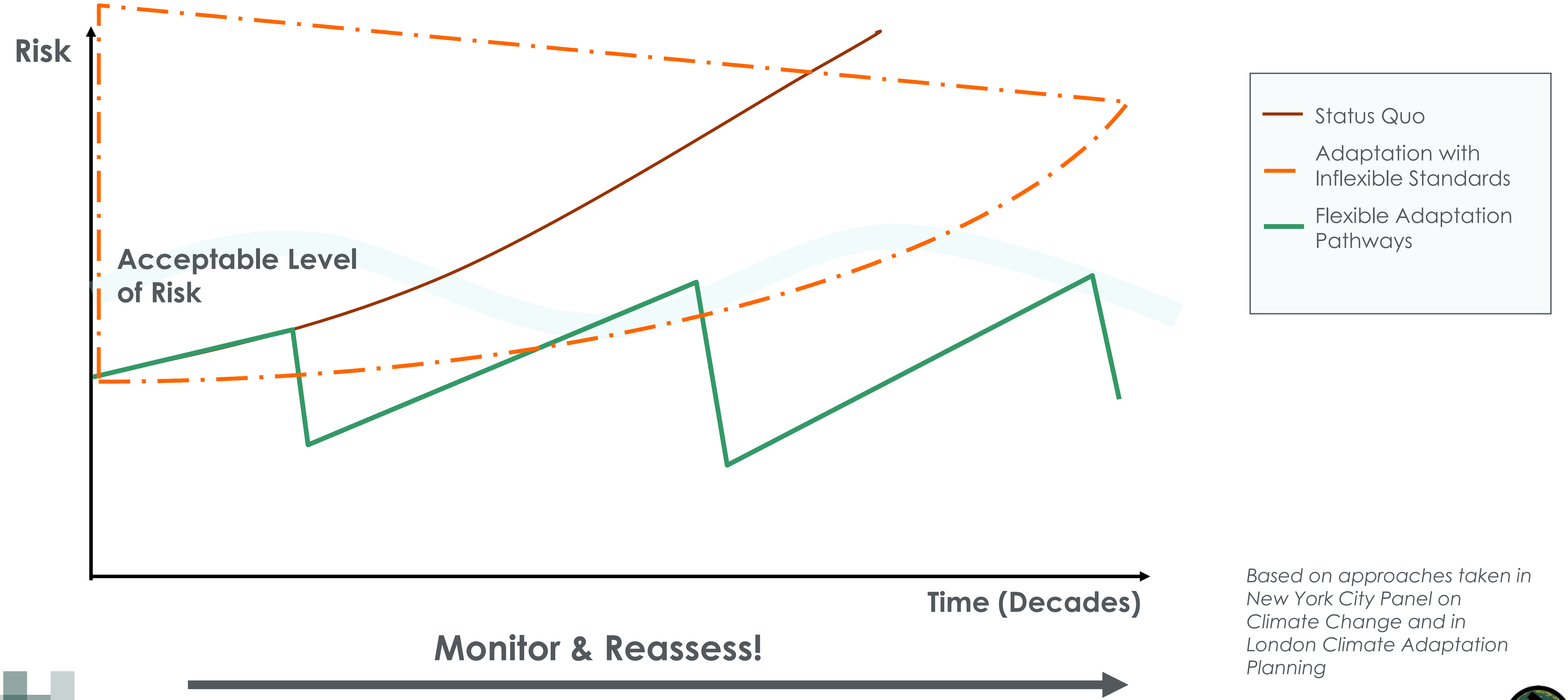
- Raise elevation of key infrastructure
- Use watertight containment of key equipment
- Have reserves of key equipment
- Install local protective barriers
- Allow some inundation in defined areas



NYC Department of Environmental Protection, 2008

Implement and Monitor

Flexible Adaptation Pathways to Manage Risk

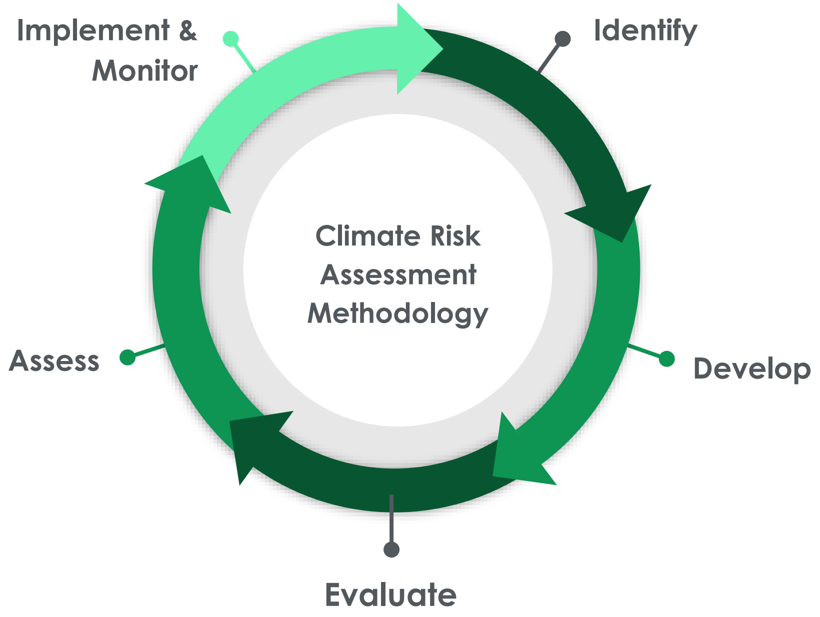


Based on approaches taken in New York City Panel on Climate Change and in London Climate Adaptation Planning

Summary and Status Check

Summary and Status Check

- **Theoretical Approach for Demand-Driven Climate Adaptation Support**
  - Identify
  - Develop
  - Evaluate
  - Assess
  - Implement and Monitor



- **Result is Contextual Adaptation Support:**
  - Motivated by stakeholder interests
  - Built upon local data and expertise
  - Utilizing right-scale climate information
  - Connecting adaptations to specific risks
  - Linked to decision structures and contexts

- **Part 2 (in two days) will elaborate on this theoretical approach as practiced by the Climate Adaptation Science Investigators (CASI) Initiative that is informing NASA climate adaptation efforts.**

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 9/21/2023
  - Access from the training webpage
  - Answers must be submitted via Google Form
  - **Due by 10/5/2023**

- **Certificate of Completion:**
  - Attend all live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

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Thank You!