TRANSPORTATION INFRASTRUCTURE CLIMATE CHANGE: VULNERABILITY, RISK, & ADAPTATION

Climate Change Risk and Vulnerability Assessment for Transportation
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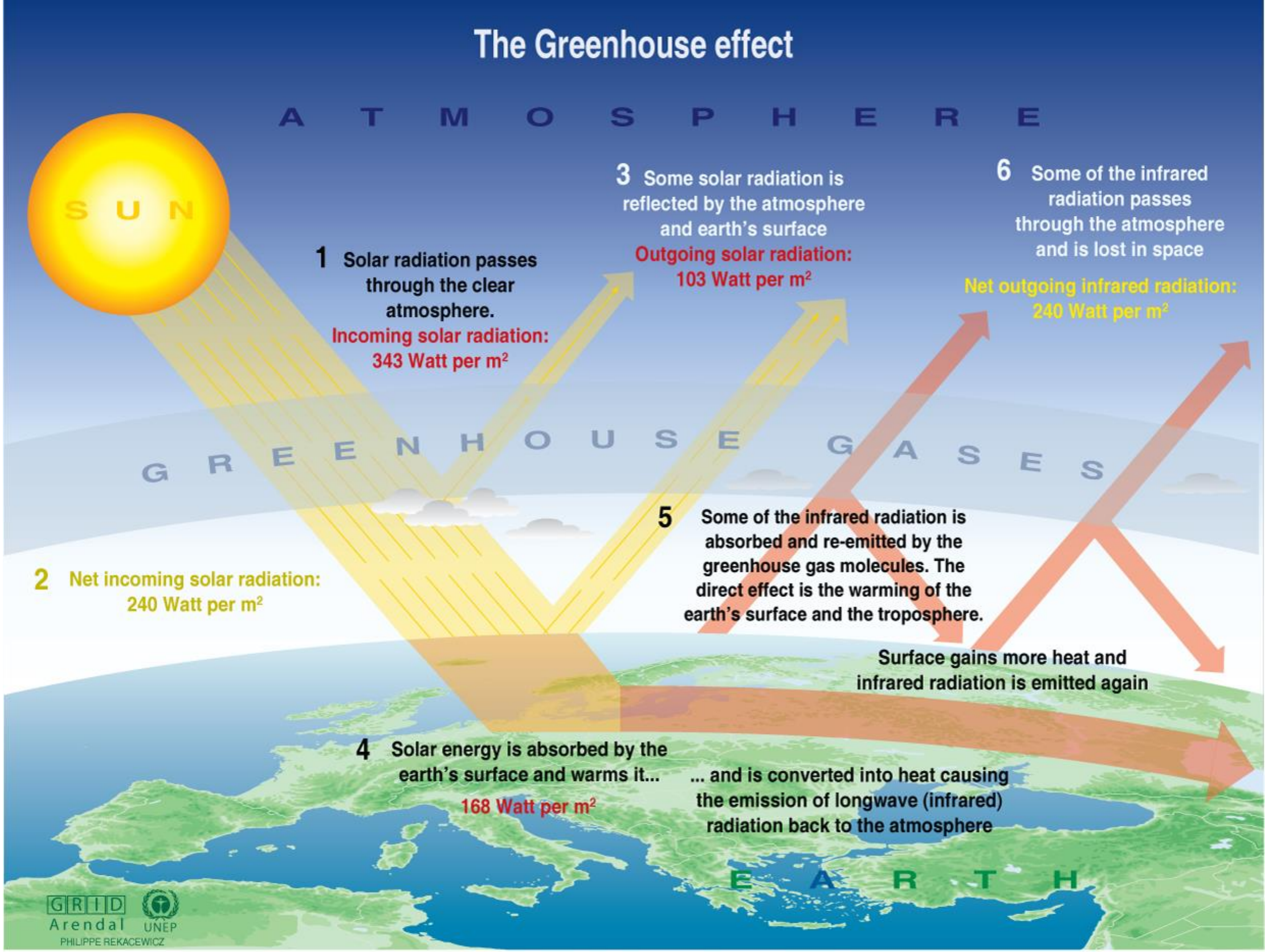
Winnipeg, Manitoba

Terry Zdan BA, MEDes
Terry.Zdan@gov.mb.ca
204-2273724

TAC ATC
TRANSPORTATION ASSOCIATION OF CANADA

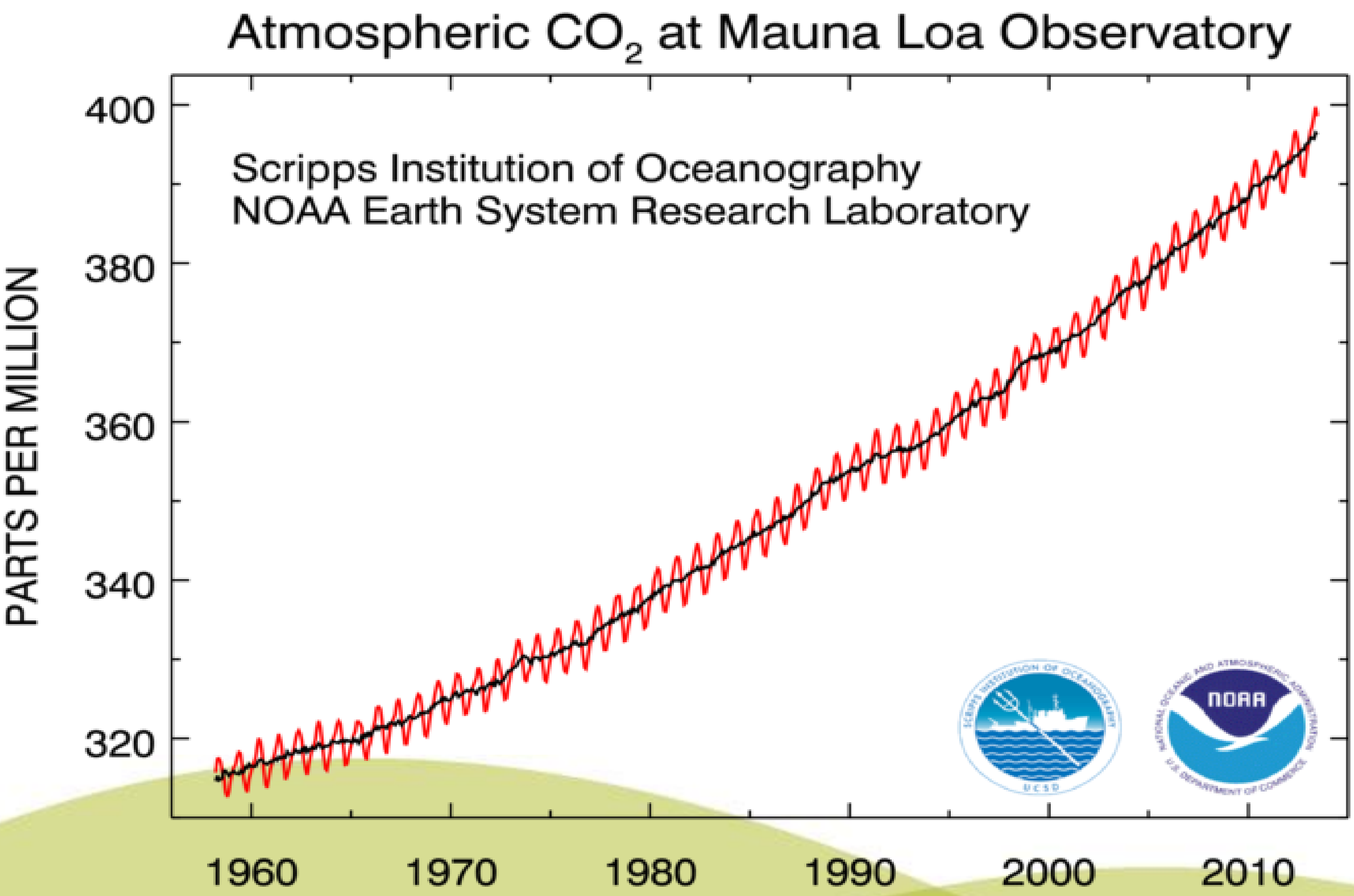
Outline

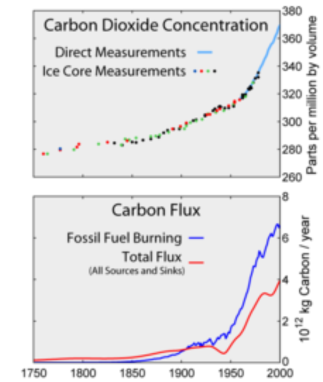
- Disclaimer
- Basic Climate Science
- Transportation Energy
- Evidence & Expected Climate Trends
- Example Climate Events and Phenomenon
- Impacts on Transportation Systems
- Vulnerability, Risk and Adaptation Assessments in the Transportation Sector
- Conclusions



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Carbon Dioxide

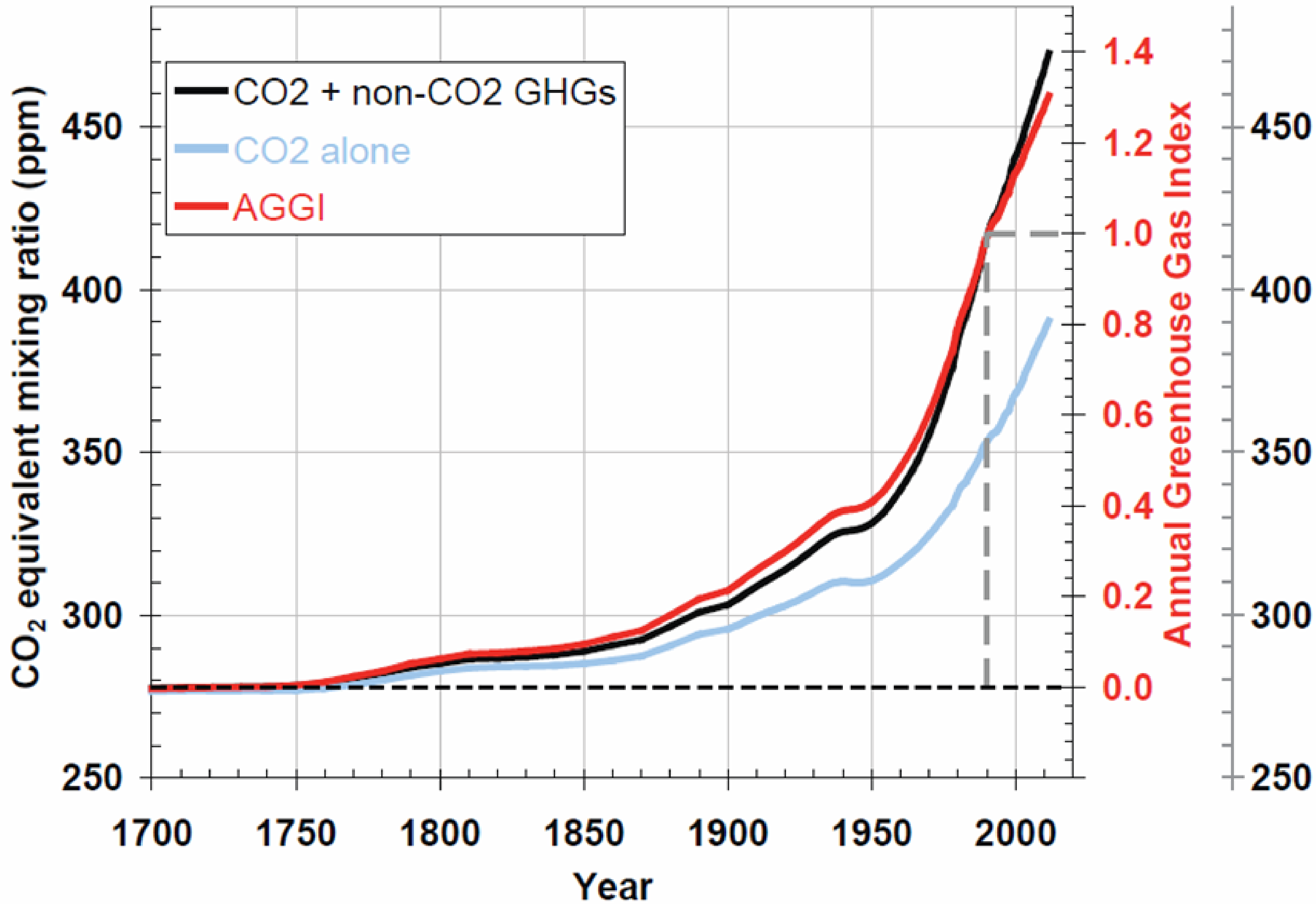




http://en.wikipedia.org/wiki/Greenhouse_gas

July 2013

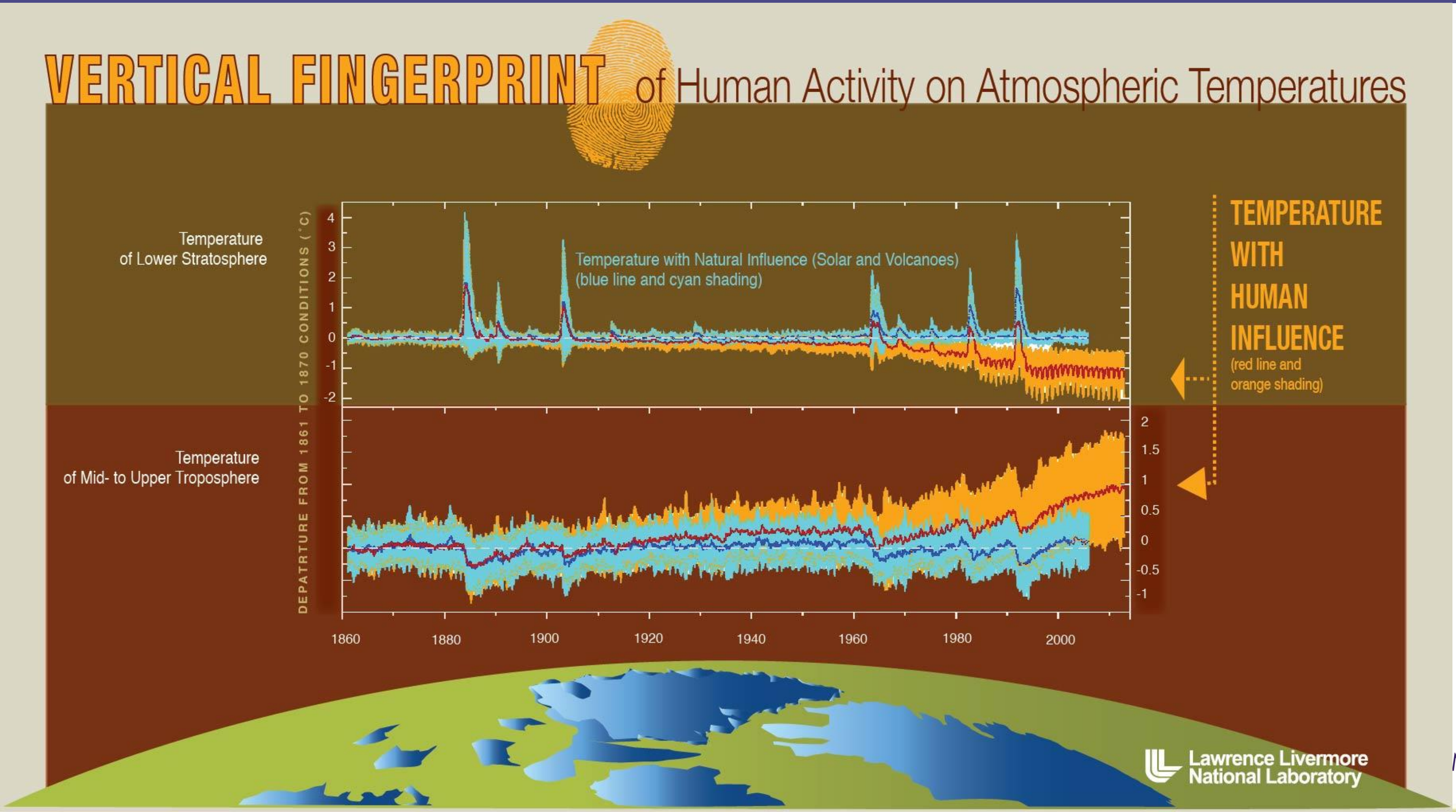
NOAA's Annual Greenhouse Gas Index



Vulnerability, Risk, Adaptation

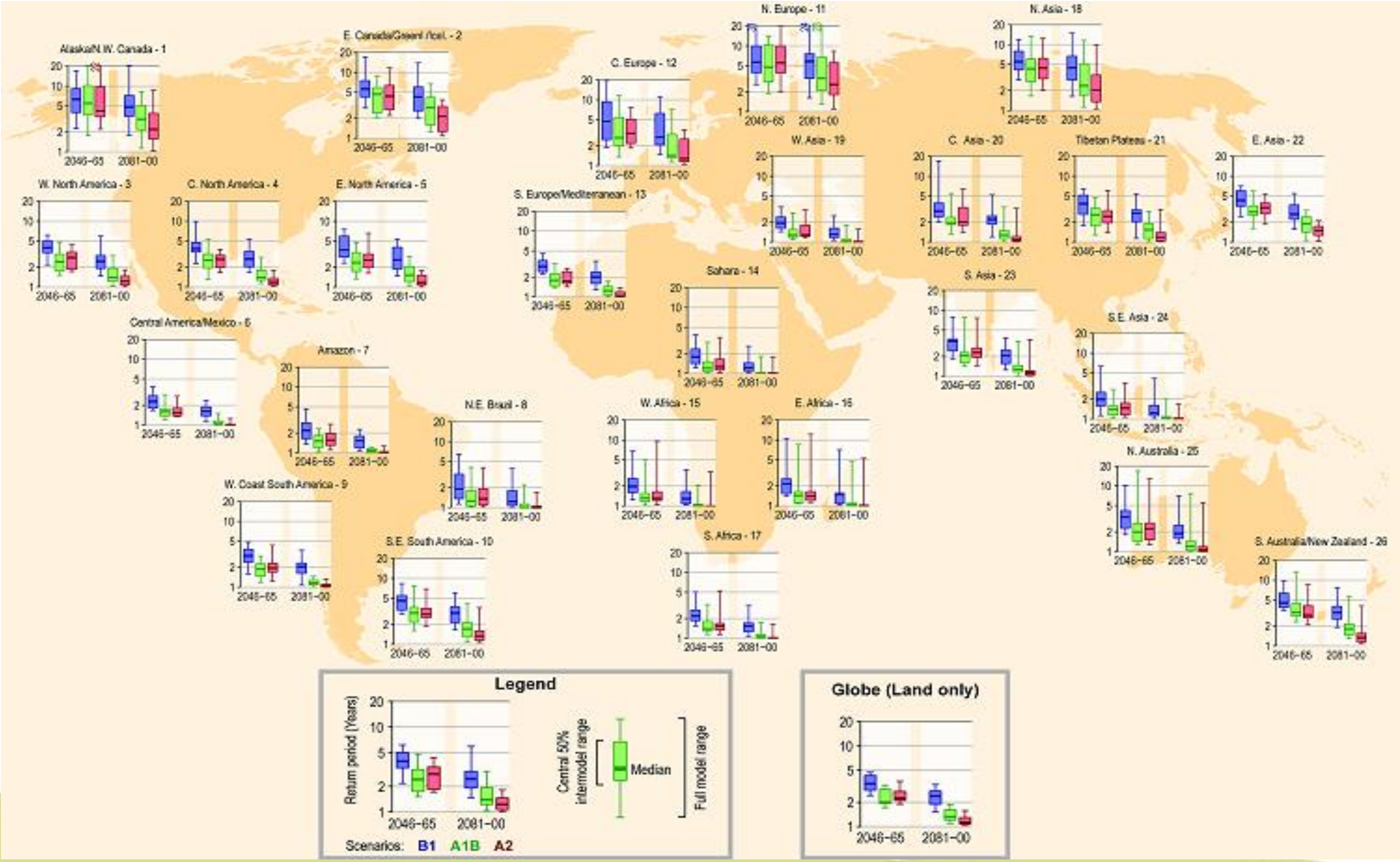
http://www.esrl.noaa.gov/gmd/aggi/

The Human Fingerprint

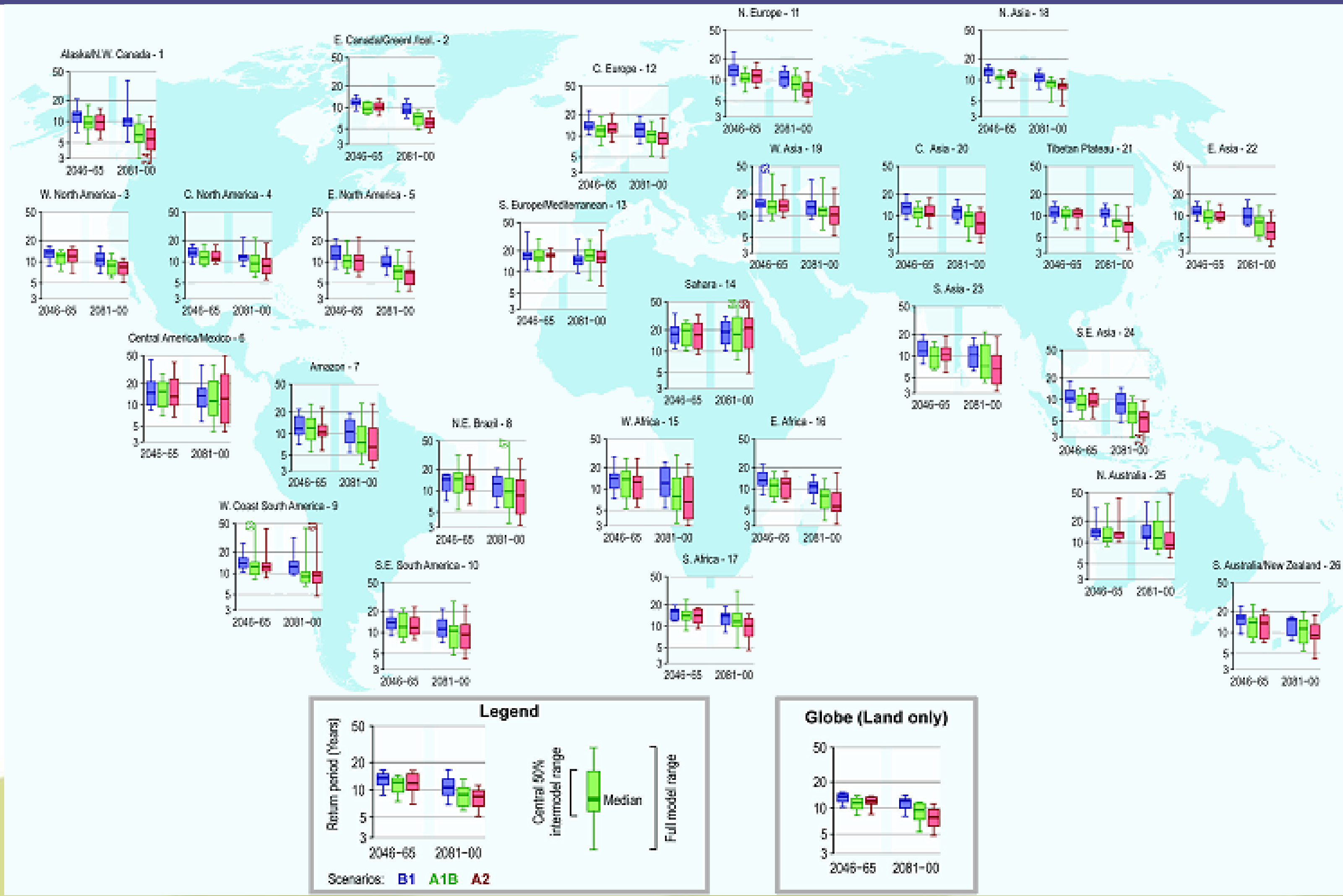


https://www.llnl.gov/news/newsreleases/2013/Sep/NR-13-09-05.html /

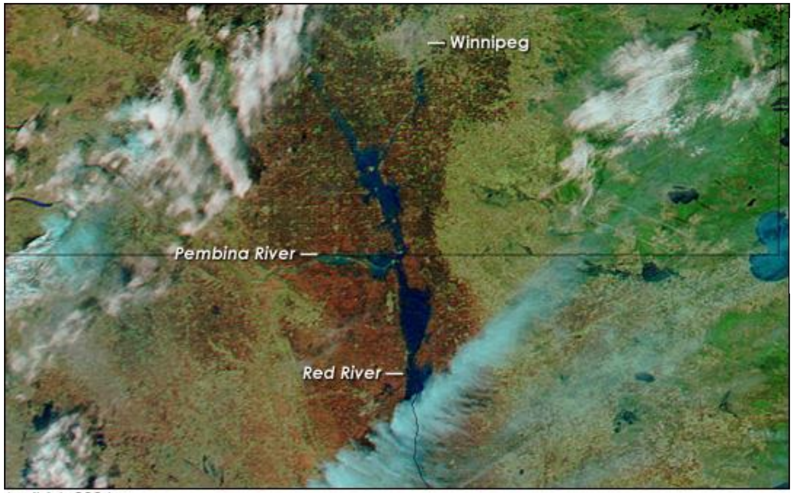
Projected return period of a 1-in-20 year extreme daily maximum temperature event in the late 20th century (1981-2000). (source: IPCC SREX 2012)



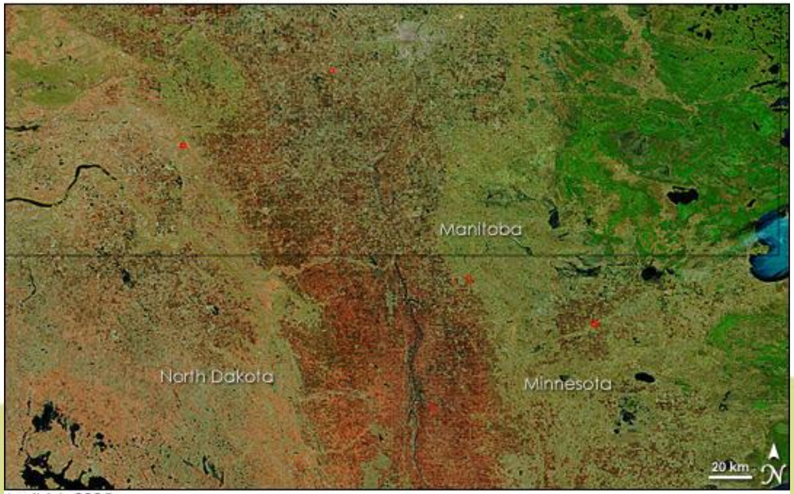
Projected return period of a 1-in-20-year extreme daily rainfall event in the late 20th century (1981-2000) (source: IPCC SREX 2012)



Red River Valley Spring Floods



April 16, 2006



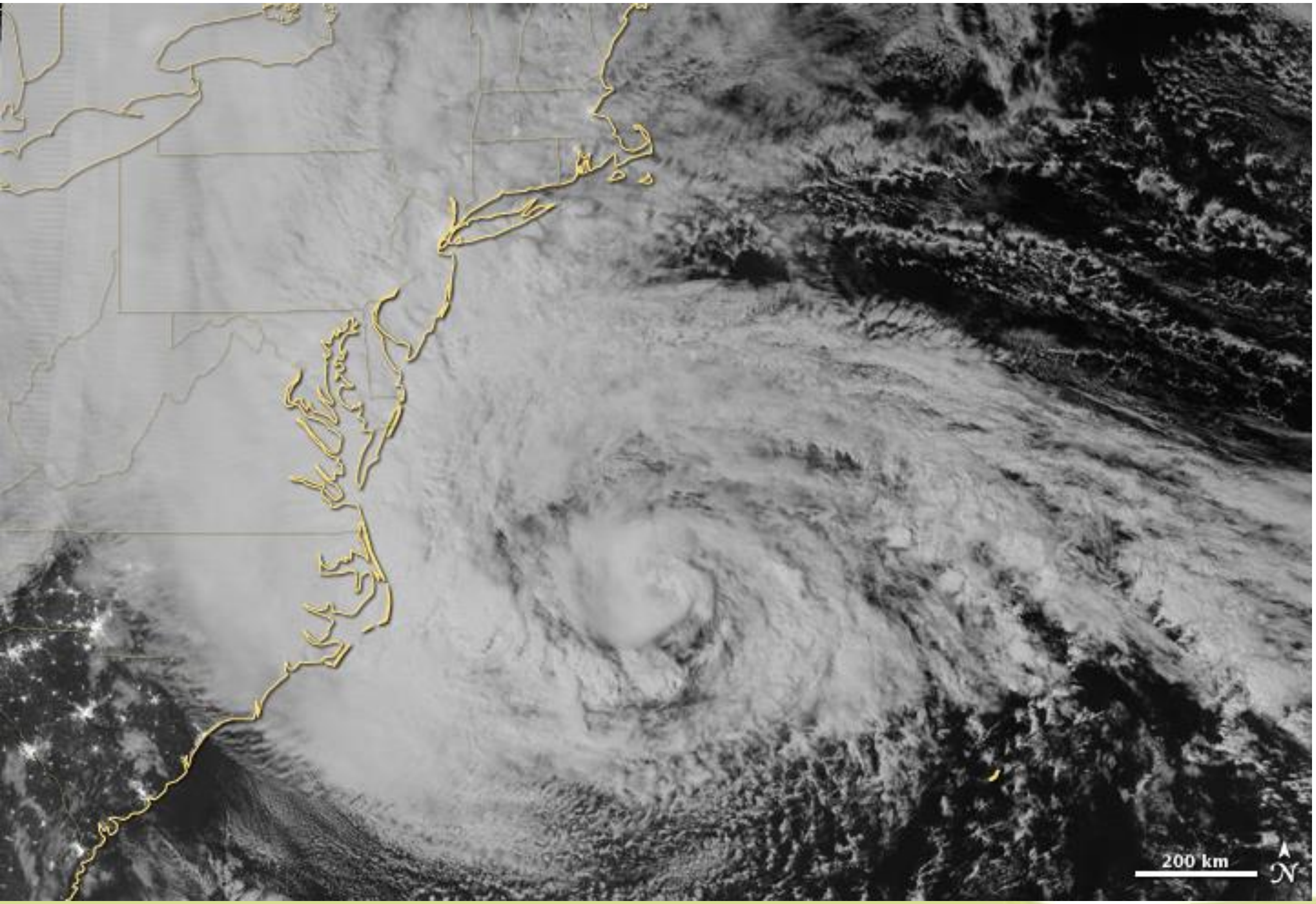
April 16, 2005

Earth Observatory

This pair of MODIS images compares the river on **April 16, 2006, to April 16, 2005.** The images are shown in false color so that water is dark blue or black, clouds are pale blue and white, and bare earth ranges from red to tan. Springtime snowmelt in 2006 has driven the Red River and some of its tributaries well over their banks. Compared to the last clear view of the floods on April 13, the river leading into Winnipeg (the cement-colored region, top center) has broadened. The flood was expected to peak in the city around April 20. The Pembina River along the border between Canada and the United States is also swollen. The region near the confluence of the Pembina and Red Rivers is covered in a wide pool of water that has grown since April 13. This flood closed the border crossing between Canada and the United States when the highway was submerged, the CBC reported. Approximately 40,000 hectares of farmland were also underwater in both countries.

In a Warming World, Storms May Be Fewer but Stronger

By Adam Voiland Design by Robert Simmon March 5, 2013



Few images are as beautiful and as terrifying as a satellite view of a hurricane about to make landfall. On October 29, 2012, the Suomi NPP satellite captured an ominous nighttime view of Sandy—an enormous hybrid storm that was part hurricane, part Nor'easter—churning off the coast of New Jersey.

NASA Earth Observatory

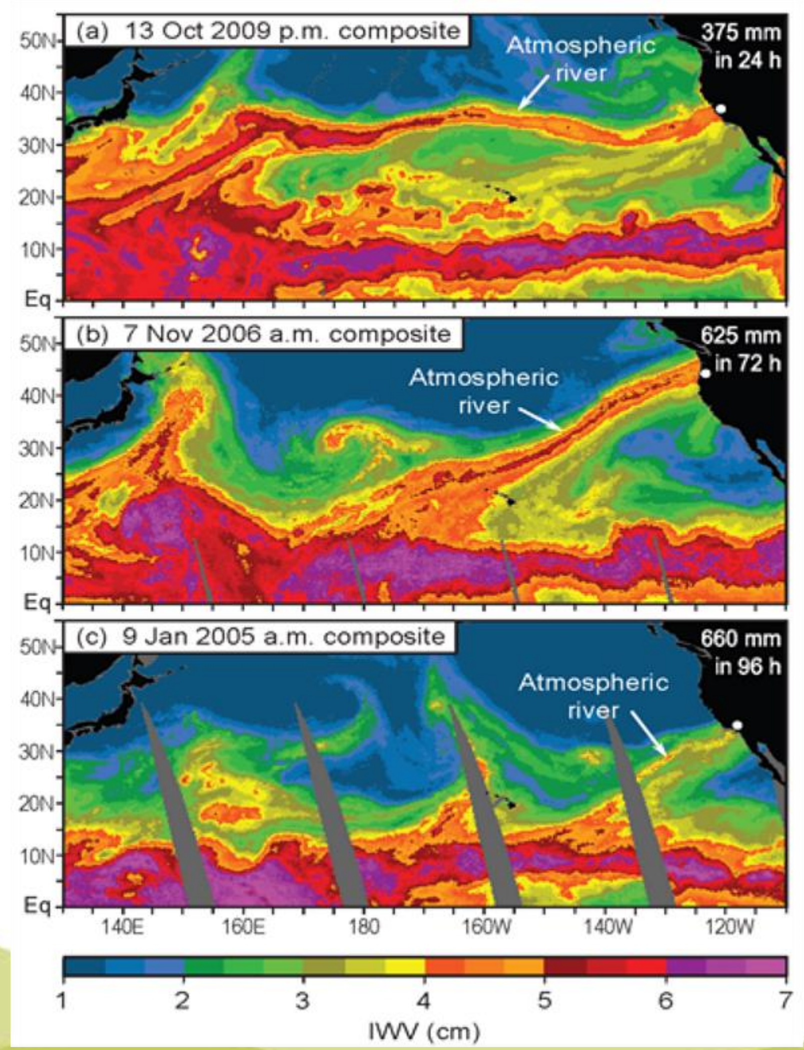
MIT

http://earthobservatory.nasa.gov/Features/ClimateStorms/

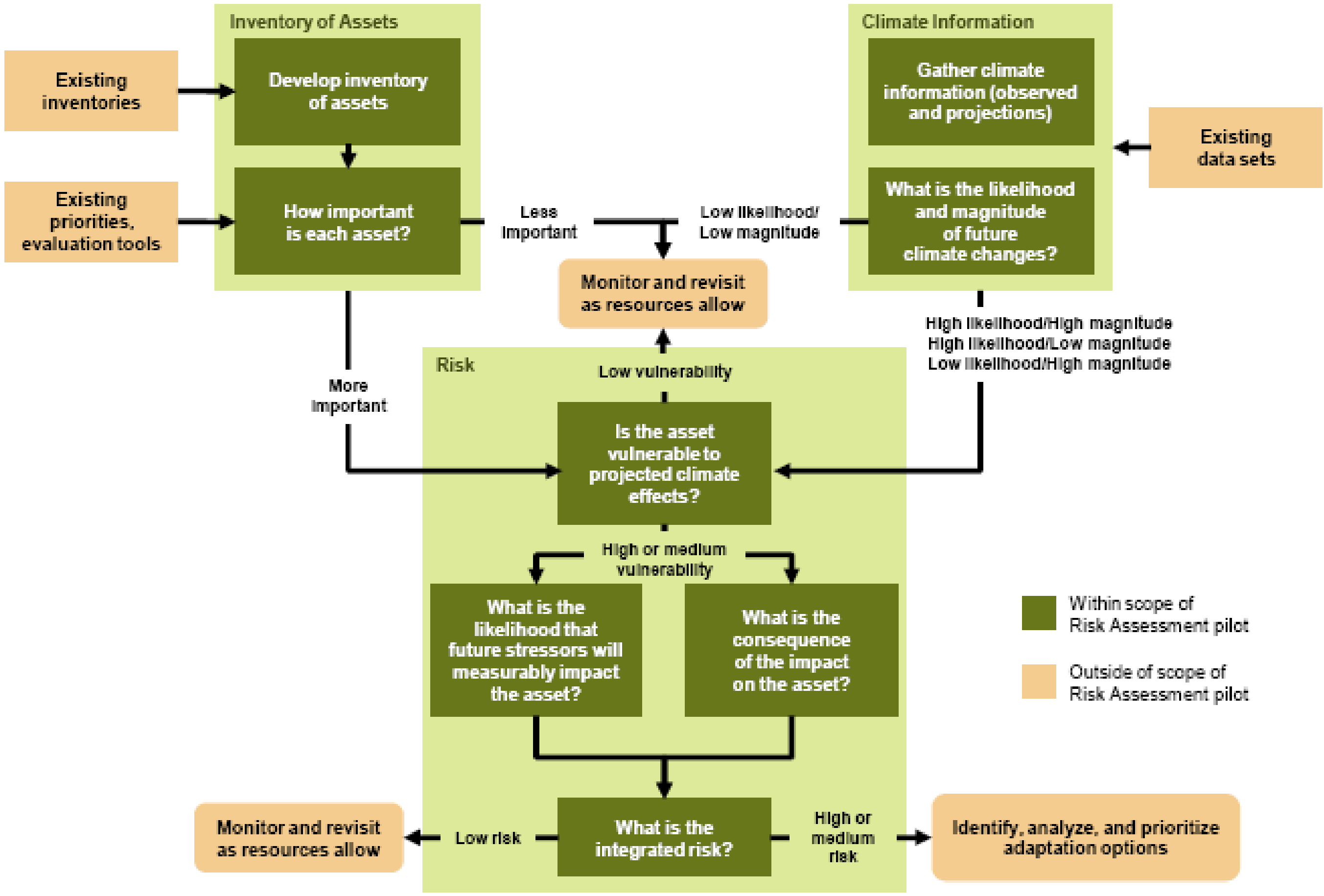
Atmospheric Rivers

- ...[These ARs] produced extreme precipitation on the US West Coast, and exhibited spatial continuity with the tropical water vapor reservoir as seen in satellite observations of integrated water vapor.

  The color scale used in these images represents the total amount of water vapor between the ocean surface and space.



Conceptual Model for Determining the Affects of Climate Change on Transportation infrastructure



Planning for Systems Management & Operations as Part of Climate Change Adaptation

Battelle
The Business of Innovation

U.S. Department of Transportation
Federal Highway Administration
March 2013

Table A.2. Transportation-Relevant Climate Change Effects Associated with Distinct Climate Events.

Category	Climate Impact	Region	Date Range	Certainty	Reference
Air Temperature Events	Increase in intensity, frequency, and duration of heat waves	CONUS	2001-2100	High confidence	Field et al., 2007
		Midwest U.S.	by 2100		USGCRP, 2009
	Increase in frequency and duration of extreme high temperature events and decrease in extreme low temperature events	CONUS	2001-2100		Christensen et al., 2007
Precipitation Events	Increase in intensity and frequency of extreme precipitation events	CONUS	2001-2100		Christensen et al., 2007
	Greater variability in precipitation events	CONUS	2001-2100		Meehl et al., 2007
		Southwest U.S.			USGCRP, 2009
Storms and Coastal Flooding	Slight poleward shift in storm tracks of extra-tropical cyclones	Mid-latitudes (30-60 °N)	2001-2100		Christensen et al., 2007
	Increase in intensity but reduction in frequency of extra-tropical cyclones	Mid-latitudes (30-60 °N)	2001-2100		Christensen et al., 2007; Meehl et al., 2007
	Increase in peak wind speeds and precipitation intensities of hurricanes	Atlantic and Eastern Pacific coasts of U.S.	2001-2102		Meehl et al., 2007
	Increase in frequency and severity of coastal flooding events	Atlantic and Pacific coasts of U.S.	2001-2100	Very high confidence	Field et al., 2007
	Increase in storm surge	Atlantic and Pacific coasts of U.S.	2001-2101	High confidence	Field et al., 2007
Wildfires	More frequent wildfires that cover larger geographic areas	CONUS	2001-2100		Field et al., 2007

MIT

Literature Review: Climate Change Vulnerability, Risk, and Adaptation Approaches

To date, three closely-related approaches are being used to help transportation decision makers consider and prepare for future climate impacts:

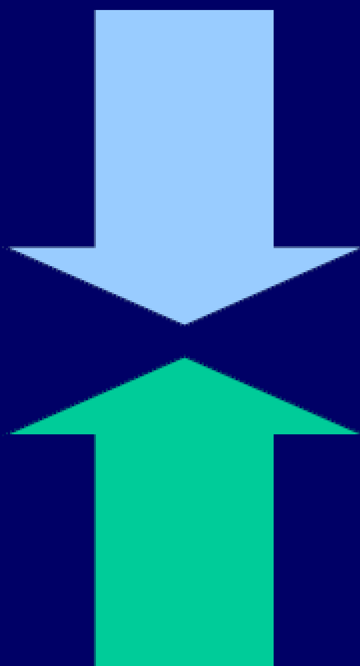
- **vulnerability** assessment,
- **risk assessment**, and
- **adaptation** assessment

The Challenge of Using Information on Climate Change

- … is we cannot forecast the exact changes
- We know the climate is changing
- We vaguely know how it will change
  - E.g., higher temperatures, sea levels, intense precipitation
- But we cannot make an accurate forecast of precisely how it will change
- So, how do we assess vulnerability?

Two Approaches for Assessing Vulnerability

CCCSN



- The scenario approach
  - Applies a "top-down" perspective
- The threshold approach
  - Based primarily on a "bottom-up" perspective
  - But also draws on top-down scenarios

The Scenario Approach

- We use scenarios of climate change to put an envelope around the uncertainty
- The scenarios should reflect ranges of:
  - Different GHG emissions
  - Different changes in the Earth's climate
  - Different changes in regional climate

CCCSN

Bottom-up Methods

- Understand your transportation system
  - What aspects of climate currently affect it?
    - Extreme heat
    - Flooding
  - What are the critical thresholds?
    - High temperatures and duration
    - Rainfall, river flow, storm surge, and duration
  - What is the current frequency (likelihood) of exceeding these thresholds?

Vulnerability Assessment

- "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007)
- The vulnerability of a given system to climate change can vary with the unique characteristics of that system including its **exposure, sensitivity, and adaptive capacity** (Snover et al., 2007)
- **Climate change** can impact a study group (or system) by **introducing new stressors** into the system, and may also **exacerbate existing stressors**

[FHWA's] Climate Change and Extreme Weather Vulnerability Assessment Framework

- is a guide for transportation agencies interested in assessing their vulnerability to climate change and extreme weather events.
- It gives an overview of key steps in conducting vulnerability assessments and uses in-practice examples to demonstrate a variety of ways to gather and process information.
- The framework is comprised of three key steps:
  - defining study objectives and scope;
  - assessing vulnerability;
  - and incorporating results into decision making.

http://www.fhwa.dot.gov/environment/climate_change/adaptation/resources_and_publications/vulnerability_assessment_framework/page00.cfm#Toc345418472

Canadian Council of Professional Engineers (Engineers Canada). 2008. Adapting to Climate Change: Canada 's First National Engineering Vulnerability Assessment of Public Infrastructure.

Relevant Infrastructure Elements	Performance Response	Relevant Climate Events and other Environmental Factors
Arterial roads	Structural integrity	High temperature
Collector roads	Serviceability	Low temperature
Local urban roads	Functionality	Extreme temperature range
Local rural roads	Operations & maintenance	Precipitation as rain
Bridges	Emergency response risk	Precipitation as snow
	Insurance considerations	Wind
	Policies & procedures	Ice accretion
	Economics	Ice force
	Public health & safety	Hail
	Environmental effects	Freeze-thaw cycles
		Groundwater
		Flooding
		Fog
		Humidity

“What keeps you up at night?"

- The Washington State Department of Transportation (WSDOT) assessed the infrastructure it owns, including roads, rail, ferry facilities, and airports.
- The WSDOT held workshops around the State, presenting information on climate projections and asking maintenance engineers and other employees with intimate familiarity with the assets, "What keeps you up at night?" to **help identify current vulnerabilities** that may be exacerbated in the future.
- Washington State Department of Transportation, *Climate Impacts Vulnerability Assessment*, November 2011.

Risk Assessment

- identify hazards that may be caused or exacerbated by climate change, and to assess the likelihood and relative consequence of these hazards in order to prioritize responses and mitigate risks (NZCCO, 2004); where the term "hazards" refers to perturbations and stresses (Turner et al., 2003).
- help identify no-regrets climate change adaptation options, that is, the uncertainty associated with the stressor is very low warranting implementation of adaptation options (Willows and Connell, 2003).

Risk Assessment Methodologies

- Preliminary Risk Screening / Qualitative Risk Assessment

- Quantitative Risk Assessment

Example Qualitative Risk Assessment

Likelihood	Consequence				
	1.Catastrophic	2.Major	3.Moderate	4.Minor	5.Insignificant
A. Very likely	1A	2A	3A	4A	5A
B. Likely	1B	2B	3B	4B	5B
C. Medium	1C	2C	3C	4C	5C
D. Unlikely	1D	2D	3D	4D	5D
E. Very unlikely	1E	2E	3E	4E	5E

http://www.fhwa.dot.gov/environment/climate_change/adaptation/resources_and_publications/vulnerability_assessment/index.cfm

Quantitative Risk Assessment

- Fewer examples exist. [flood damage curves]
- Deterministic "what if" or "worst case" scenario analyses are based on historical data without consideration of recurrence or probability.
- Probabilistic Risk Assessment (PRA) attempts to associate probabilities with specific hazardous events (e.g., storm surge).
- Further, some approaches attempt to superimpose incremental climate-related hazards on existing hazards in order to assess potential changes in frequency and severity in the future.
- Methods or frameworks for quantitatively assessing and prioritizing risks and direct and indirect consequences, or probable losses, due to climate-related impacts are not well established.
- Models do exist to help understand existing natural hazards that may be exacerbated by climate change and to quantify damage.

Adaptation Assessment

An adaptation assessment is defined by the IPCC as "**the practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility"** (IPCC, 2007). Long-term planning can prepare for potential climate changes and address the uncertainty with changing conditions. For example, roads and bridges are designed to be maintained and replaced in a certain time frame. Incorporating improvements in design and maintenance can enhance the lifetime expectancy of this infrastructure, and improve resilience to climate impacts.

Identify Adaptation

There are three types of adaptation responses relevant to transportation planning which address climate impacts at varying time scales:

PROTECT - RETREAT - ACCOMODATE

These responses can be put into practice through investing in infrastructure and technology or changes in management approaches (PPIC, 2008; CCSP, 2008):

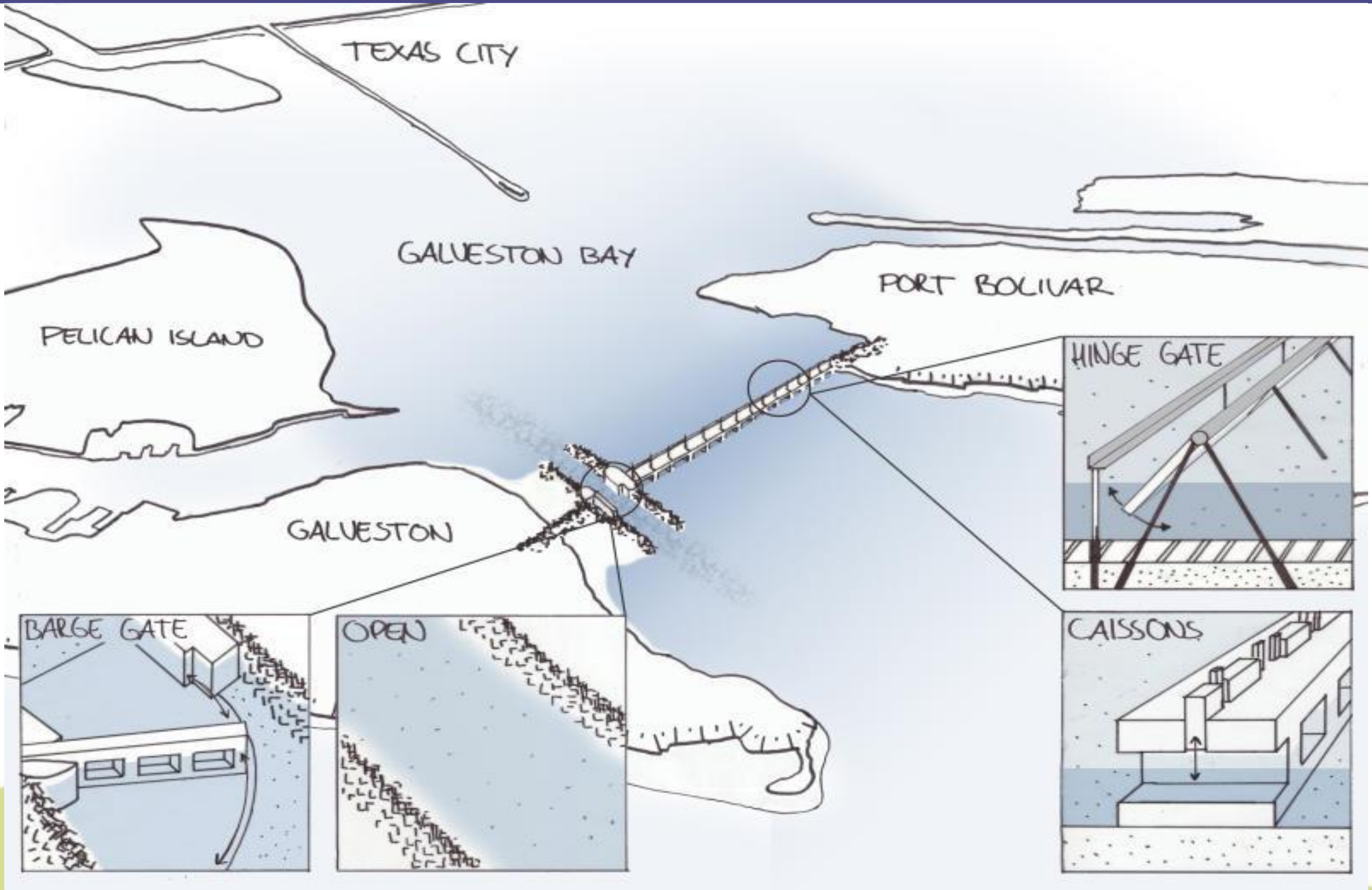
PROTECT includes such options as redesigning the infrastructure or instituting measures to reduce the climate impact (such as armoring against storm surges).

RETREAT includes abandonment of the infrastructure.

ACCOMODATE includes operational strategies that can be implemented to reduce the climate impact (such as pumping water after a flood event).

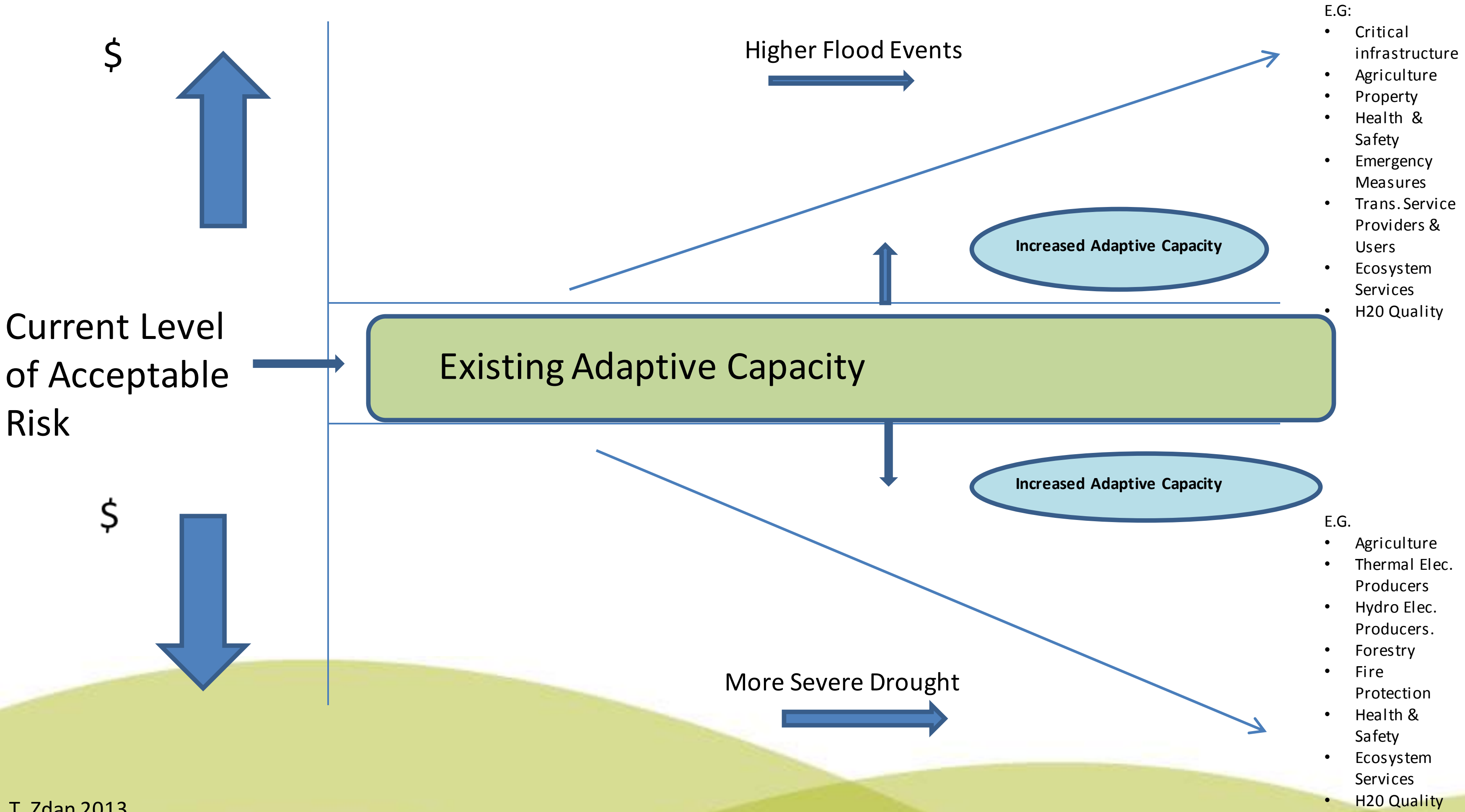
http://www.fhwa.dot.gov/environment/climate_change/adaptation/resources_and_publications/vulnerability_assessment/index.cfm

The "Ike Dike" Concept : Houston



Texas surge barrier. (Credit: Image courtesy of Delft University of Technology)

CBA : Adaptation Assessment



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Conclusion : A Trio

- VULNERABILITY Assessment
- RISK Assessment
- ADAPTATION Assessment

A VRA Framework

Ontario

Step 1: Set Context and Build Team	• Define the study area and identify environmental themes (ie., ecological, social, and economic) and indicators • Build the team and engage experts, stakeholders, and partners
Step 2: Assess Current Vulnerability	• Describe the system's current sensitivity and exposure to climate and non-climatic stresses • Describe the degree of adaptive capacity of the system
Step 3: Develop and Apply Future Scenarios	• Develop and apply future climate scenarios • Consider anticipated non-climatic stresses (e.g., human population growth, land use)
Step 4: Estimate Future Vulnerability and Risks	• Identify and describe future impacts • Determine future vulnerability and categorize uncertainty • Describe the likelihood and consequences of vulnerabilities through socio-economic, political, and environmental evaluations • Determine areas at highest risk • Communicate initial findings to key organizations
Step 5: Develop Adaptation Options	• Based on the risk analysis, determine potential adaptation options • Prioritize adaptation options considering economic feasibility, social acceptability, ecological suitability, and technical and institutional feasibility (e.g., barriers and opportunities)
Step 6: Implement and Mainstream Adaptation	• Determine highest priority adaptation actions for implementation • Communicate accomplishments • Monitor adaptation actions and vulnerabilities over time • Acquire new knowledge, learning, and insights, and modify adaptation actions as required

ITERATIVE PROCESS

Thank You