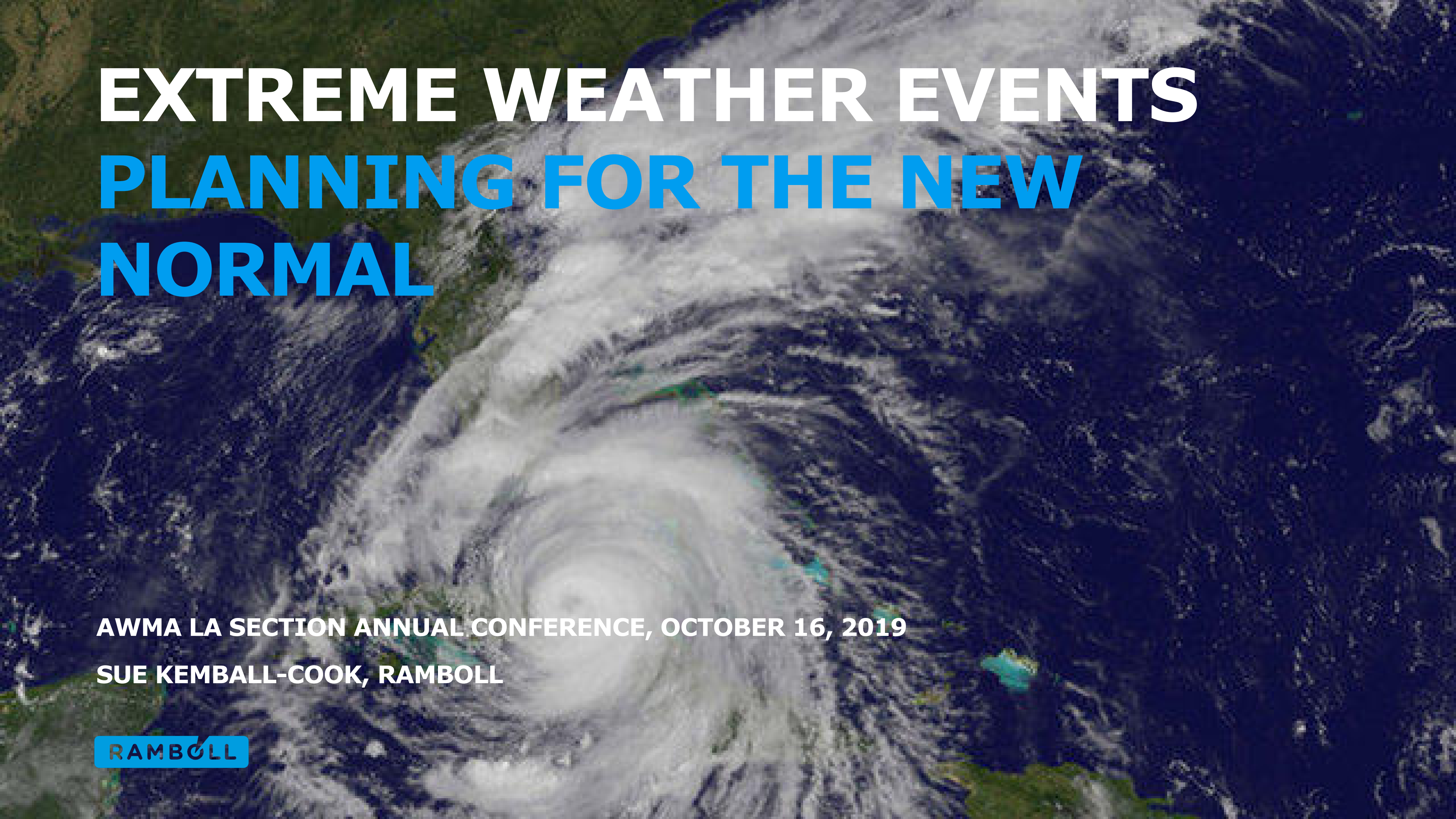

EXTREME WEATHER EVENTS
PLANNING FOR THE NEW NORMAL

AWMA LA SECTION ANNUAL CONFERENCE, OCTOBER 16, 2019

SUE KEMBALL-COOK, RAMBOLL

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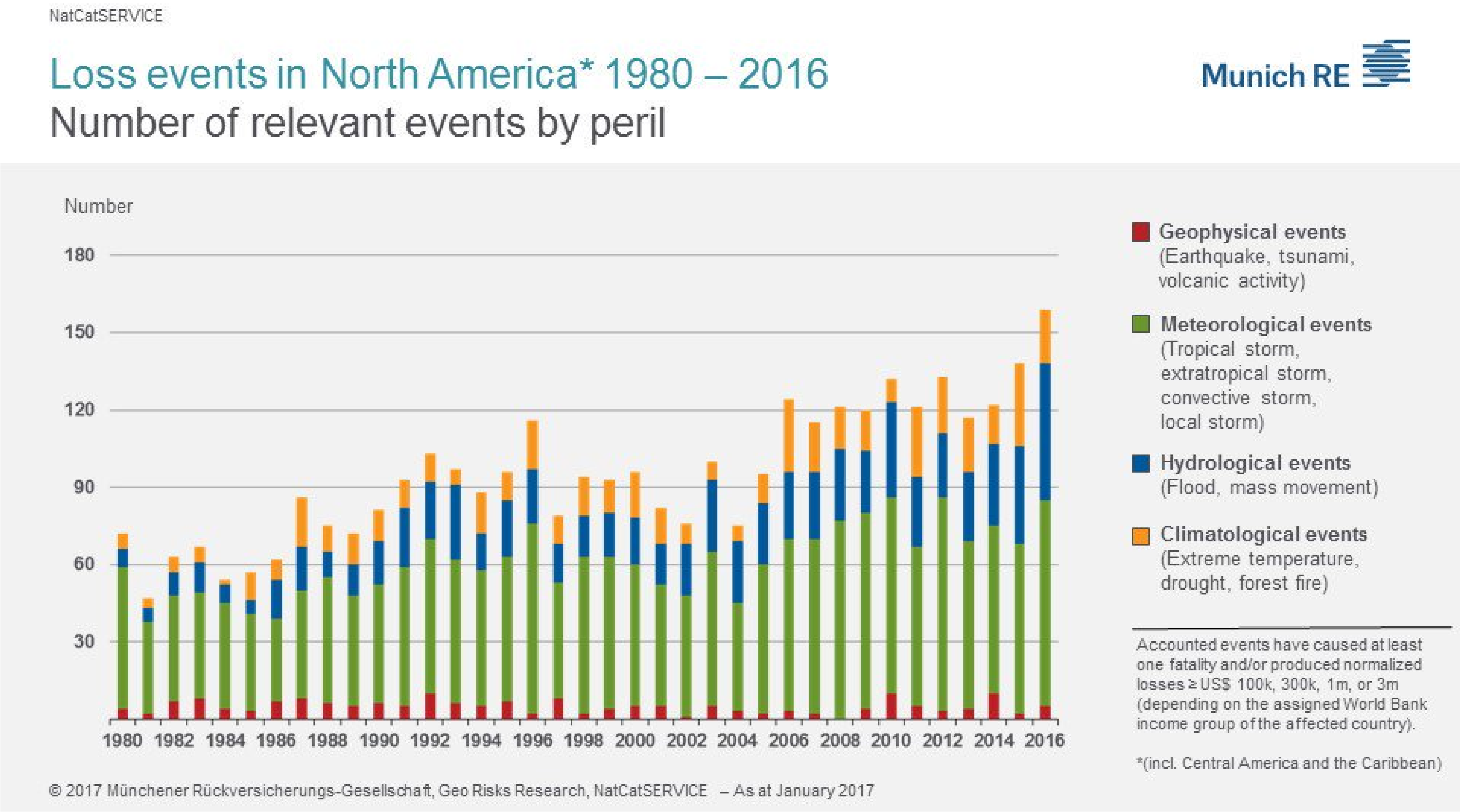
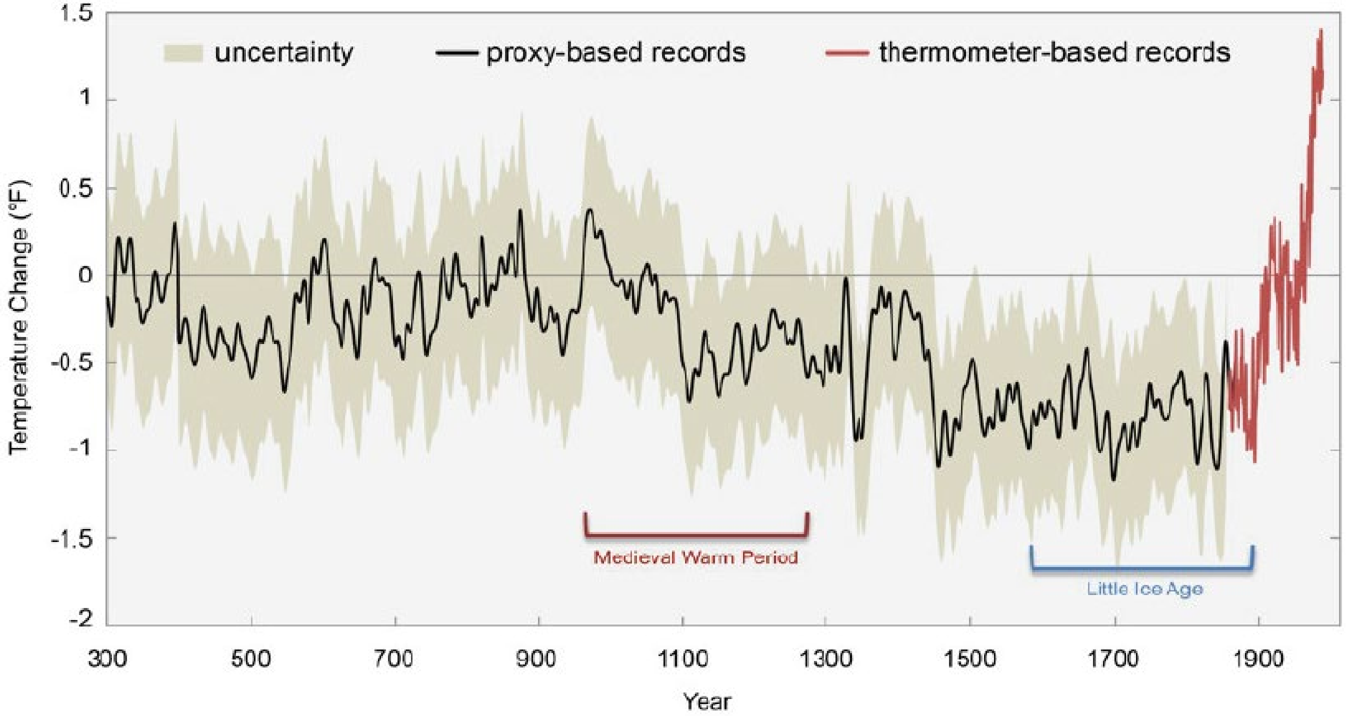
INCREASING NORTH AMERICAN LOSS EVENTS



RAPID CLIMATE CHANGE

Changes in Northern Hemisphere Temperature
Relative to 1961-1990 Average



We're in new territory

- Unprecedented changes in climate
- Recent increases in extreme and damaging events projected to continue

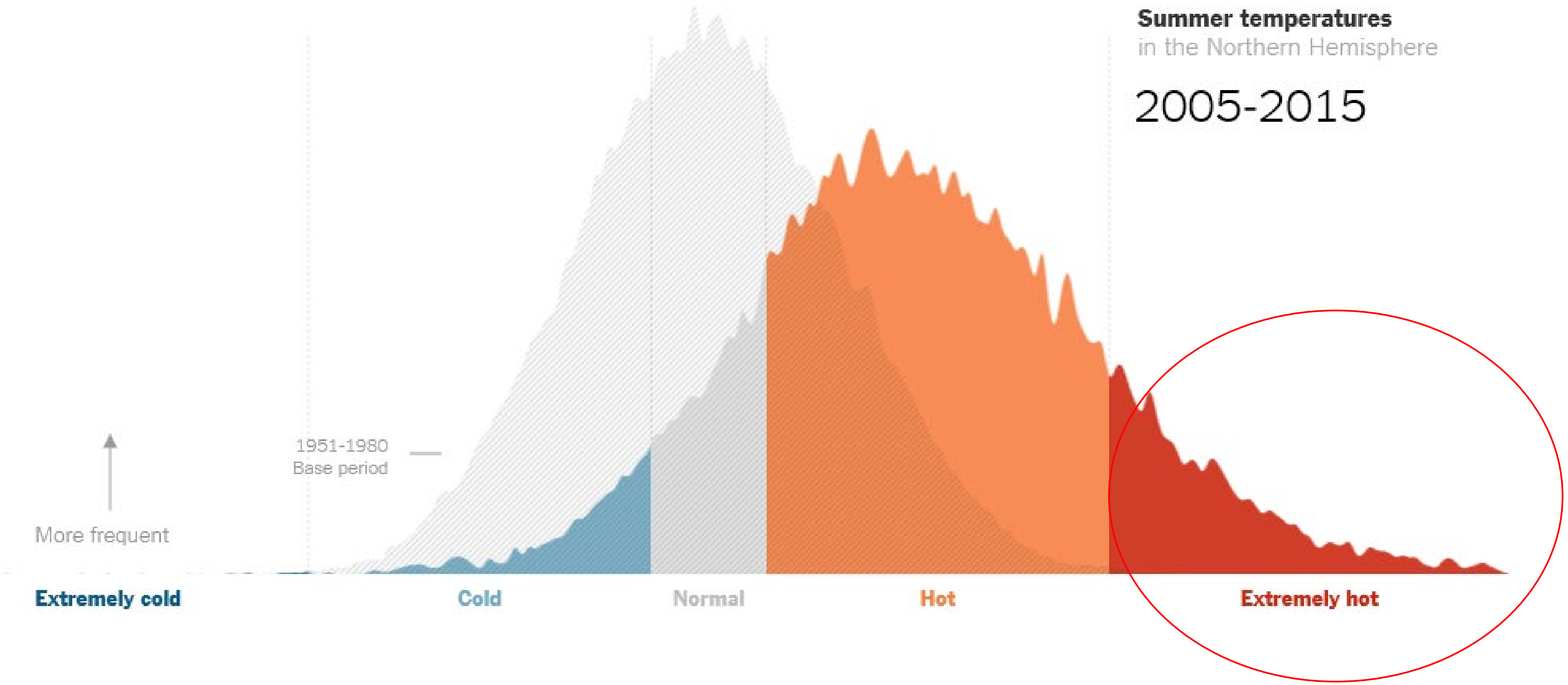
Figure from US 4th National Climate Assessment:
Source: adapted from Mann et al. 2008

INCREASING PREVALENCE AND INTENSITY OF EXTREMES

The New York Times

It's Not Your Imagination. Summers Are Getting Hotter.

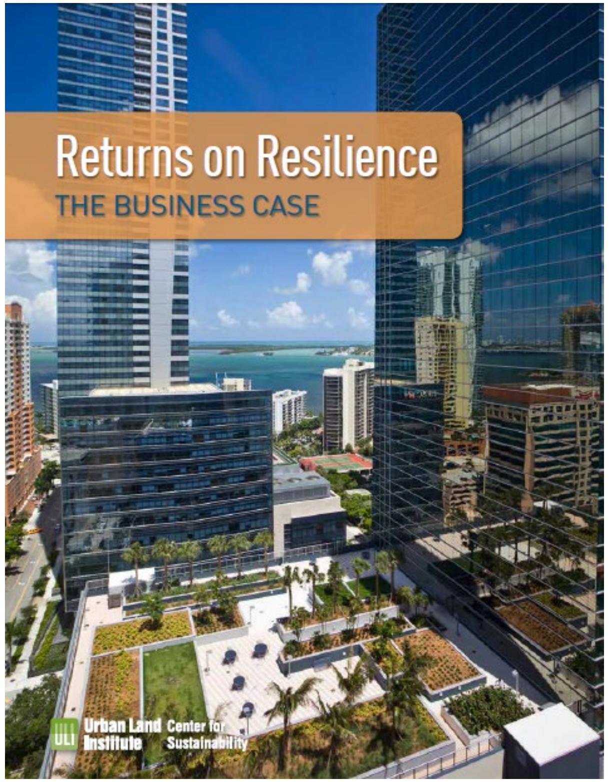
By NADJA POPOVICH and ADAM PEARCE JULY 28, 2017



EXTREME EVENTS ARE AFFECTING BUSINESSES NOW

THE WALL STREET JOURNAL.

Show Us Your Climate Risks, Investors Tell Companies



PROJECTED CHANGES IN EXTREME WEATHER

- Increase in frequency and intensity of heavy precipitation
- Increases in hurricane rainfall rates and intensity
- Little change/reduction in total number of hurricanes
- Increase in number of Category 4 and 5 hurricanes
- Increased frequency of conditions that can produce severe thunderstorms, hail and tornadoes
- Increase in landfalling atmospheric river events on west coast
- Rising max and min temperatures, more heat waves
- Increased frequency and intensity of droughts and wildfires

How certain is the science?

High confidence

Medium confidence

Low confidence

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PLANNING FOR THE FUTURE WHEN EXTREMES ARE SHIFTING

- **Infrastructure is typically designed using data from the past**
  - FEMA flood hazard maps based on historical data
  - Stormwater handling infrastructure designs based on historical rainfall data
  - Sea level assumed static in many areas of the US

- **In a changing climate, decisions based solely on data from the past will underestimate risk**

- **How to safeguard facilities, infrastructure, contaminated sites, etc. against extreme weather impacts without going overboard?**

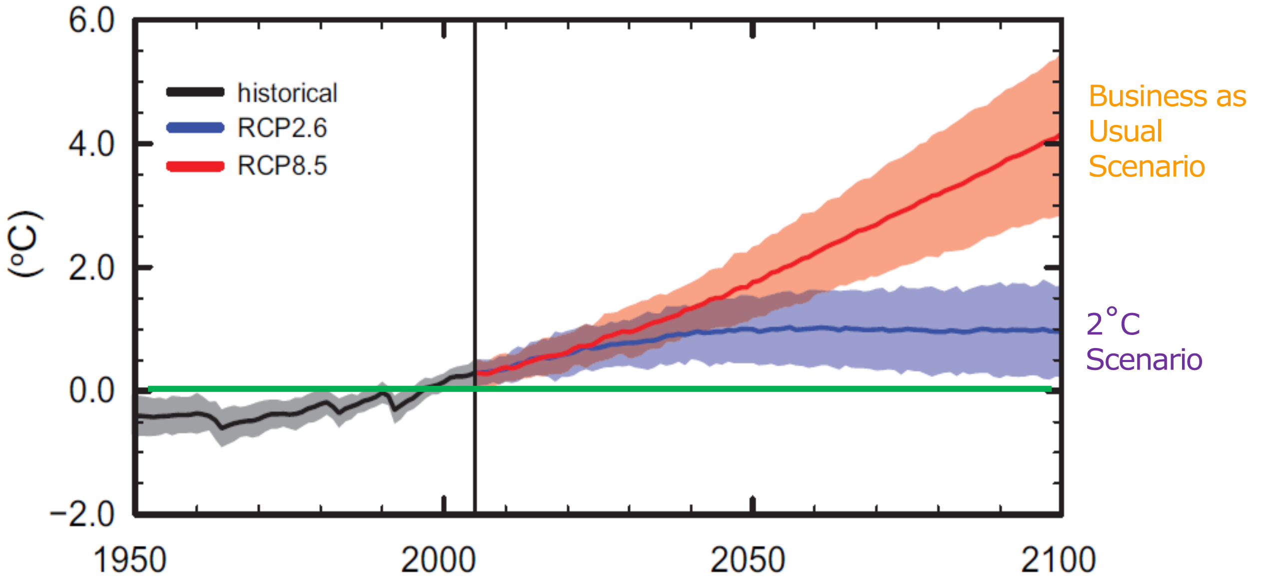
EXTREMES AND BROWNFIELD SITES

Planning for management and cleanup of contaminants is often based on current climate and hydrologic conditions

- Rising seas may submerge or erode coastal remediation sites or drastically alter physical and chemical hydrologic conditions (e.g. saline intrusion)
- Rising/falling water table affects passive remediation systems
- Heavy rains can
  - mobilize contaminants
  - exceed capacity of underground pumping systems
  - compromise surface impoundments
  - cause erosion, landslides, subsidence
- Increased drought prevalence affects vegetation, water covers
- Infrastructure typically designed for present/past climate (levees, retention ponds)

THE CLIMATE WILL CONTINUE TO CHANGE-BUT HOW MUCH?

IPCC Global Mean Temperature Projections



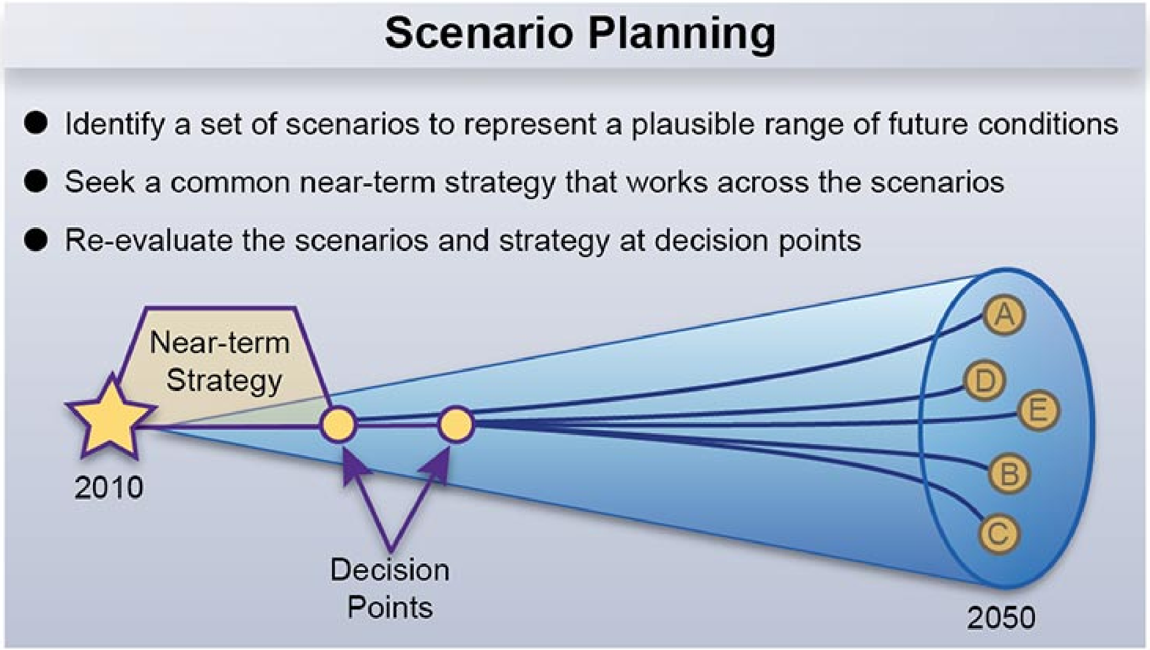


Figure from Melillo et al. (2014): 3rd US National Climate Assessment

- Past greenhouse gas (GHG) emissions commit us to some level of climate change
- The magnitude of change and impacts depend on future GHG emissions and the response of the climate system
- Planning for long-lived assets using scenario analysis

METHOD FOR PHYSICAL CLIMATE RISK/IMPACT EVALUATION

DATA GATHERING

Gather data on past and present weather risks and sensitivities

- Has site experienced weather-related damages in the past decade?
- What were the associated costs?

CLIMATE RISK SCREENING

Use climate model data to assess future climate-related risks for each scenario

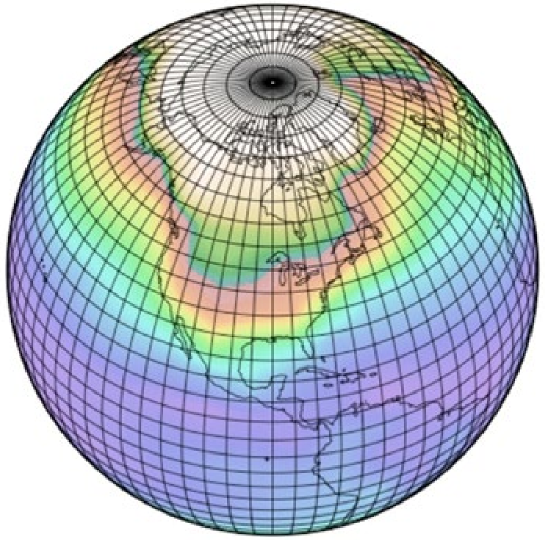
- Average and extreme temperatures and precipitation
- Degree heating and cooling days, heat wave prevalence
- Drought/flood/wildfire prevalence and intensity
- Changes in availability of resources (water, energy, etc.)
- Sea level/storm surge

IMPACT ASSESSMENT

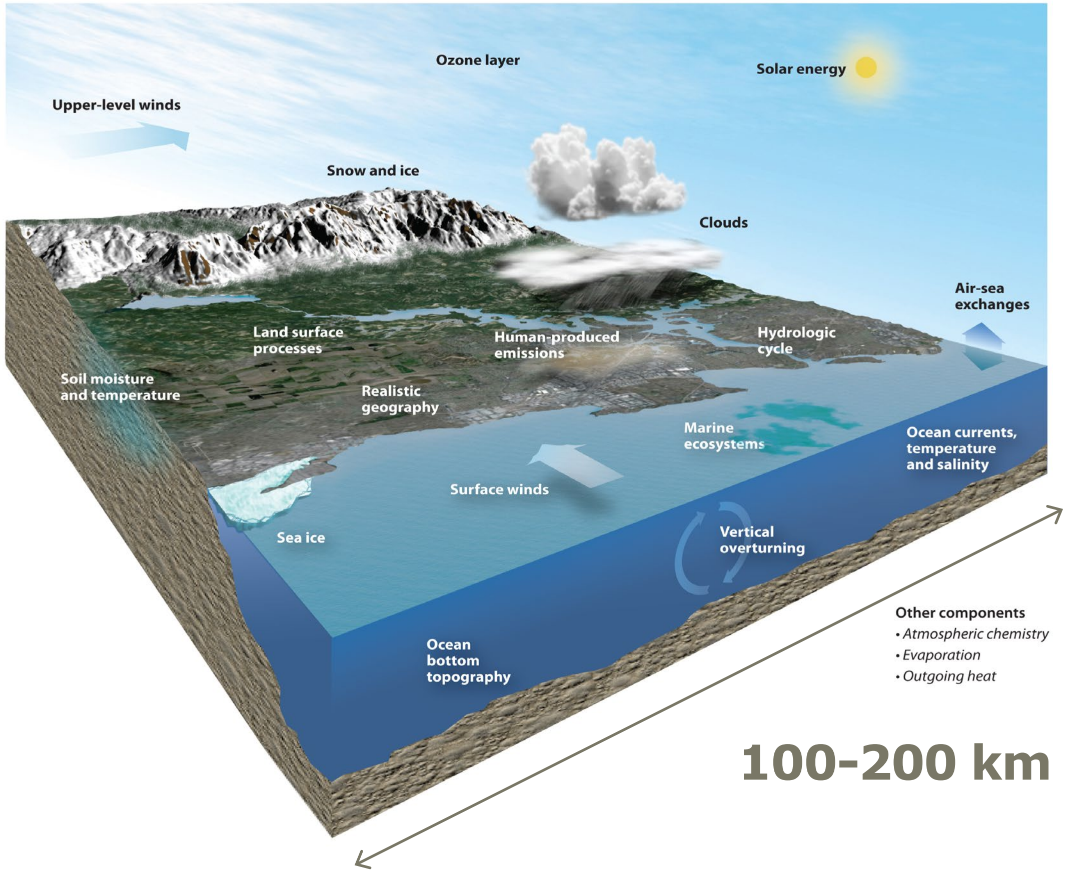
Assess potential impact on the asset and site operations

- Risks to infrastructure
- Threats to resource availability (water, power)
- Supply chain/logistical/operational impacts from extreme weather
- Potential for financial impacts (losses, changes in opex, capex, revenues, production)

PROJECTIONS OF THE FUTURE
GLOBAL CLIMATE MODELS

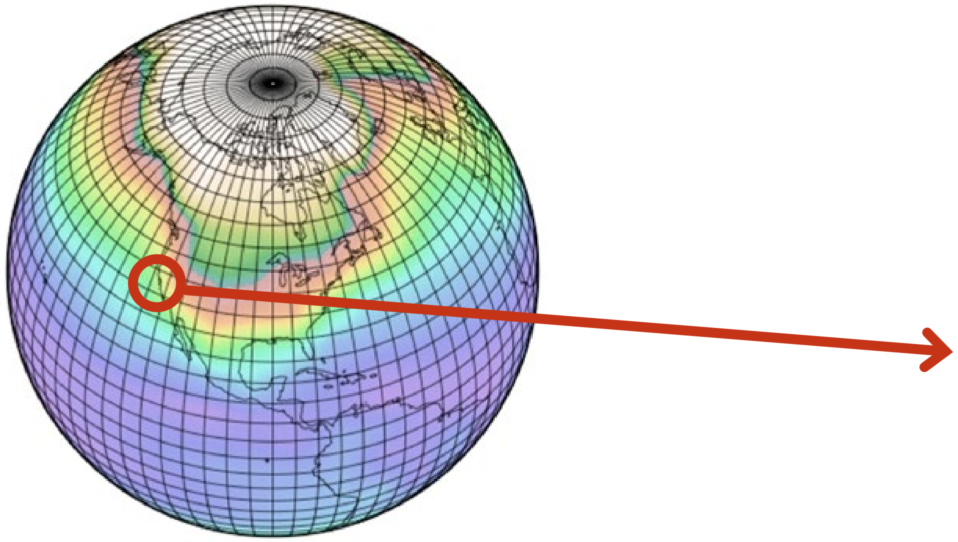


- Based on well-established physical principles
- Run by research groups around the world
- Peer-reviewed credible estimates of future climate at continental scales
- Adapted for local impact assessments by downscaling

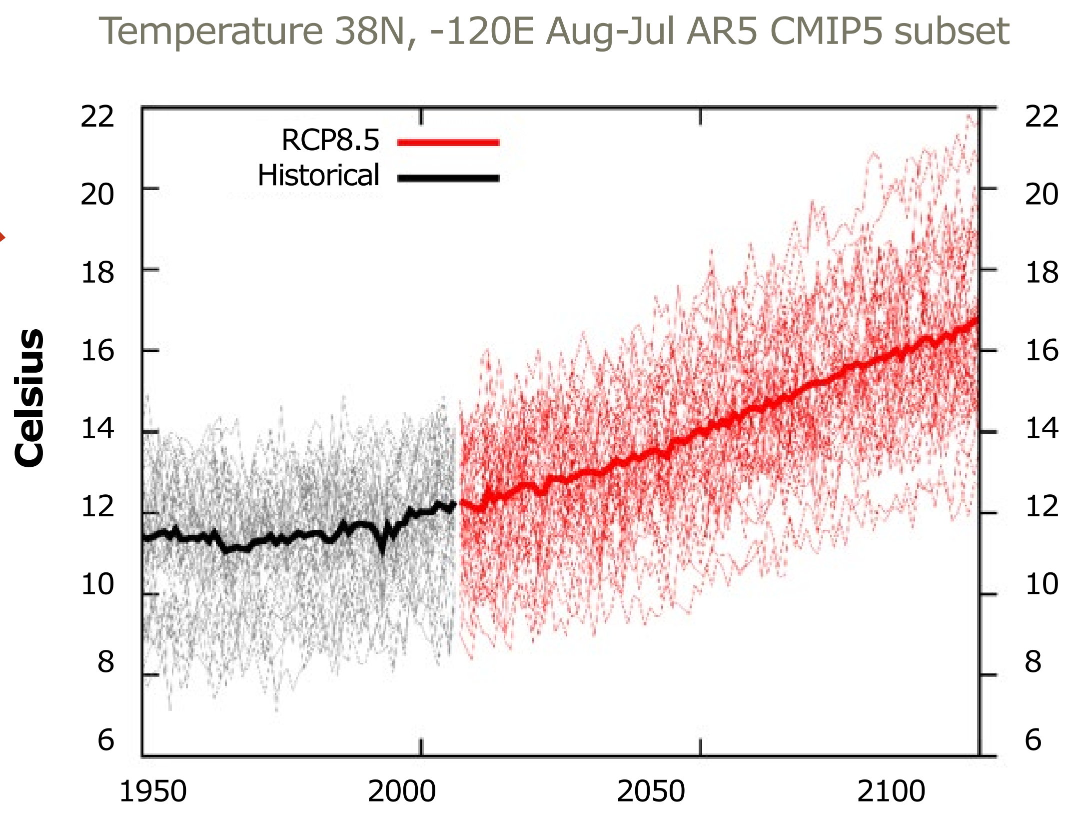


Climate model figures: NCAR

EXAMPLE OF GLOBAL CLIMATE MODEL SIMULATION OUTPUT



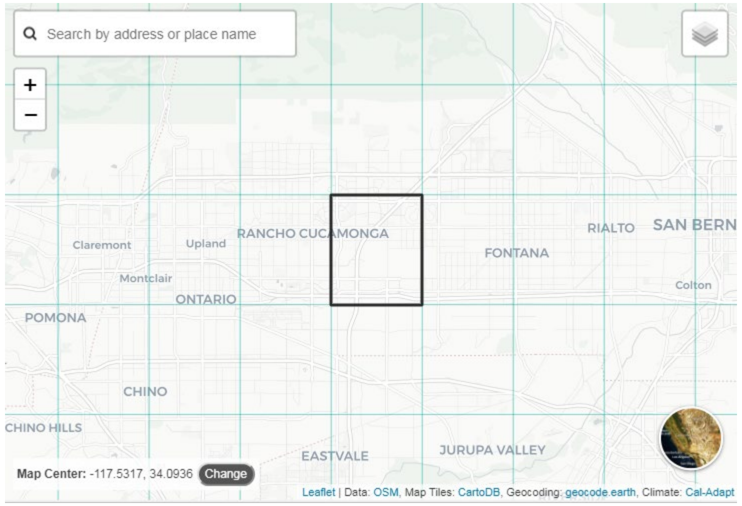
GROUND LEVEL AIR TEMPERATURE

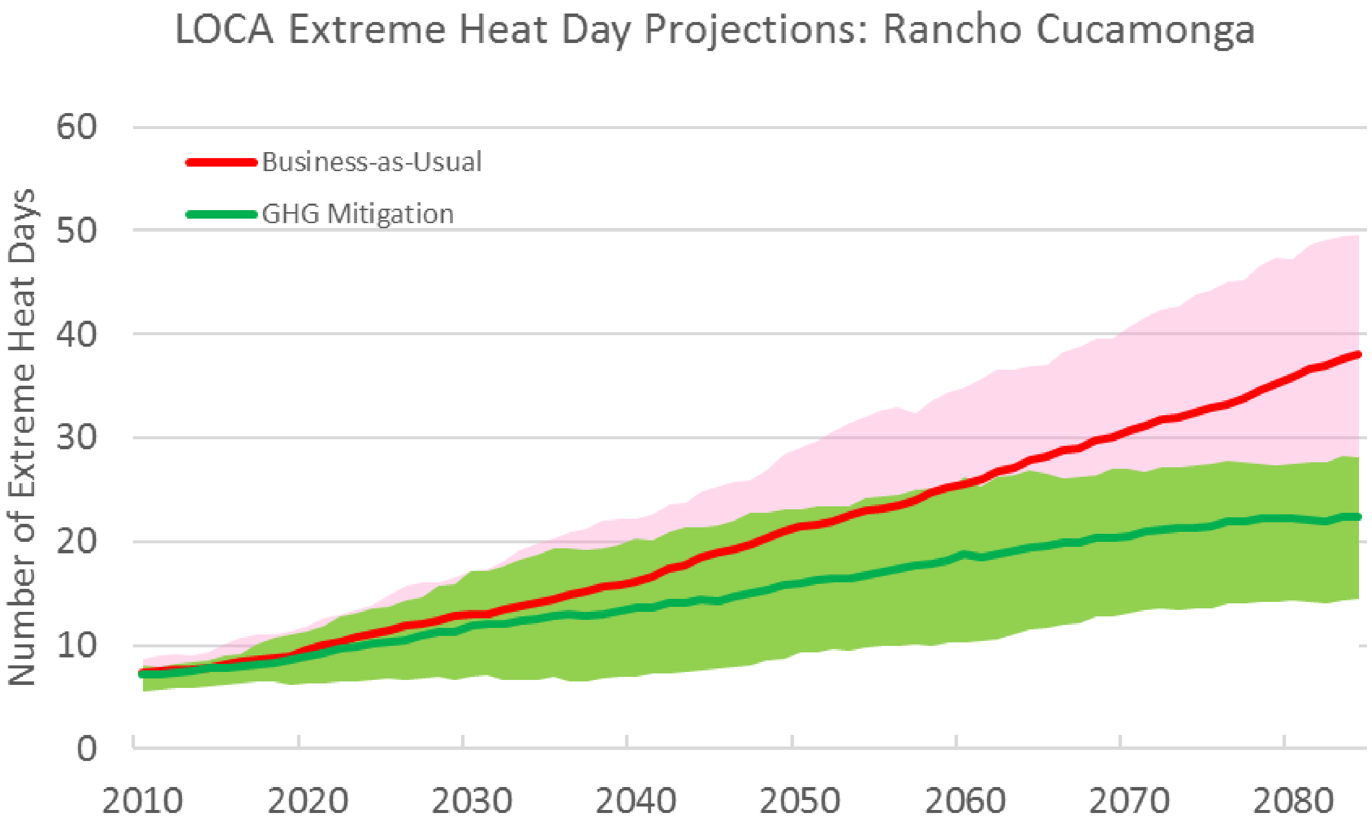


- Projection of future temperature, rainfall etc. for each grid cell
- More than 40 models, each with different response to GHG forcing
- Multi-model mean often taken to be best estimate of the future

HOW WILL TEMPERATURE EXTREMES CHANGE?

- Shading shows range of downscaled climate model results
  - How will GHGs evolve?
  - Uncertainty of using computer models to evaluate climate change

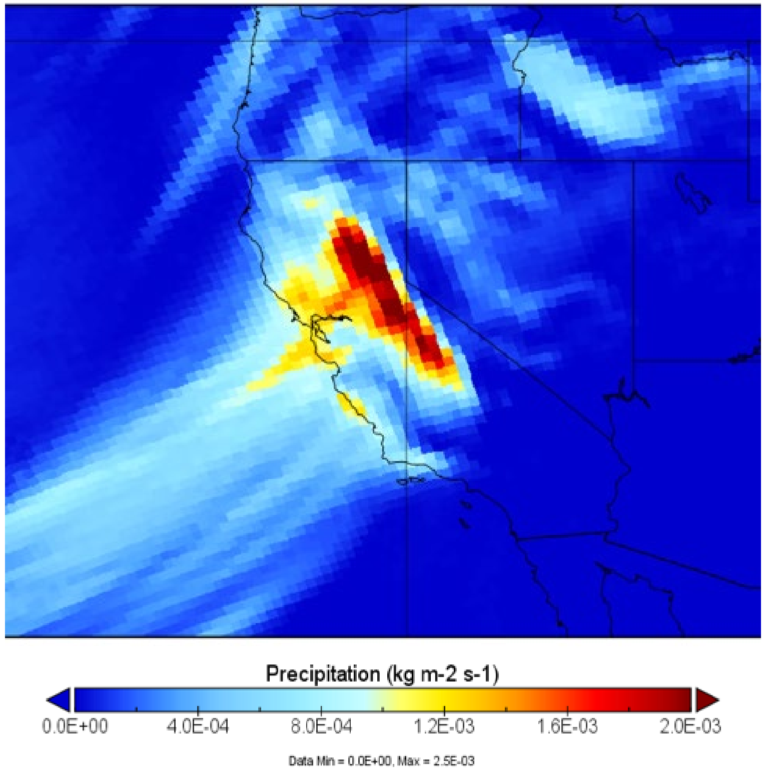




Extreme heat day plot developed from downscaled LOCA projections using data from HadGEM2-ES, CanESM2, CNRM-CM5 and MIROC-5 GCMs.

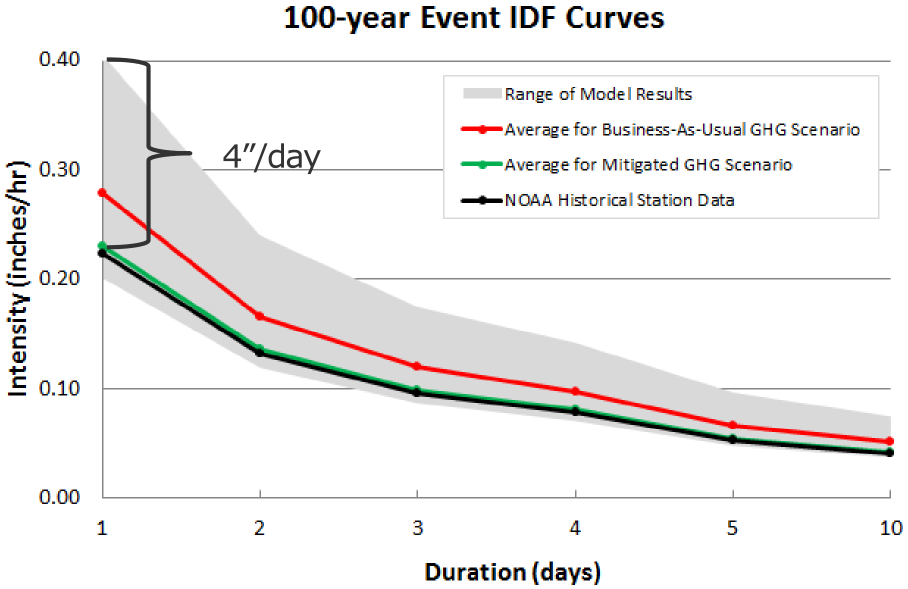
HOW WILL RAINFALL EXTREMES CHANGE?

DOWNSCALED FUTURE RAINFALL FROM REGIONAL CLIMATE MODEL



Extreme Value Statistical Analysis

FUTURE RAINFALL EXTREMES FOR FLOOD RISK MODELING



- Client's engineering team used the climate model rainfall analysis in hydraulic modeling
- Designed a levee to protect a new neighborhood from increasingly intense future storms

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FLOODING FROM EXTREME PRECIPITATION

- Screening level modeling of flooding from heavy precipitation
- Map shows rail access point and region alongside roadway are vulnerable to flooding
- USGS elevation data plotted with SCALGO mapping tool
  - Terrain elevation resolution is about 10 m x 10 m
  - Higher resolution LIDAR data available in many areas
  - Drone elevation data acquisition

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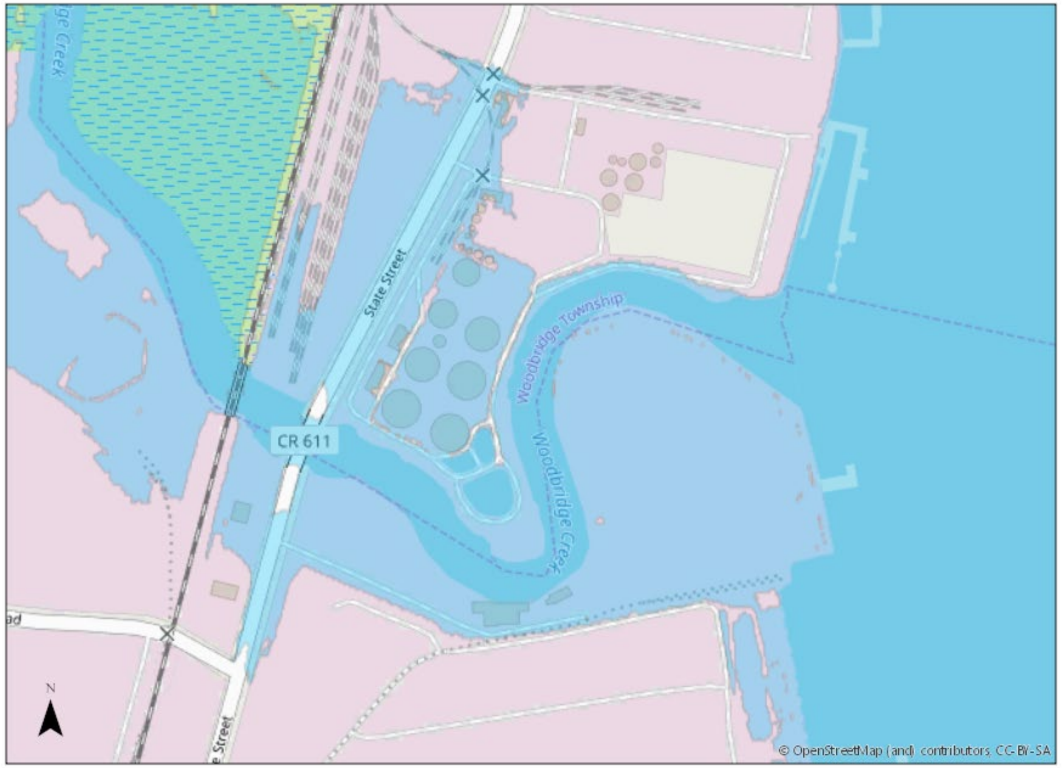
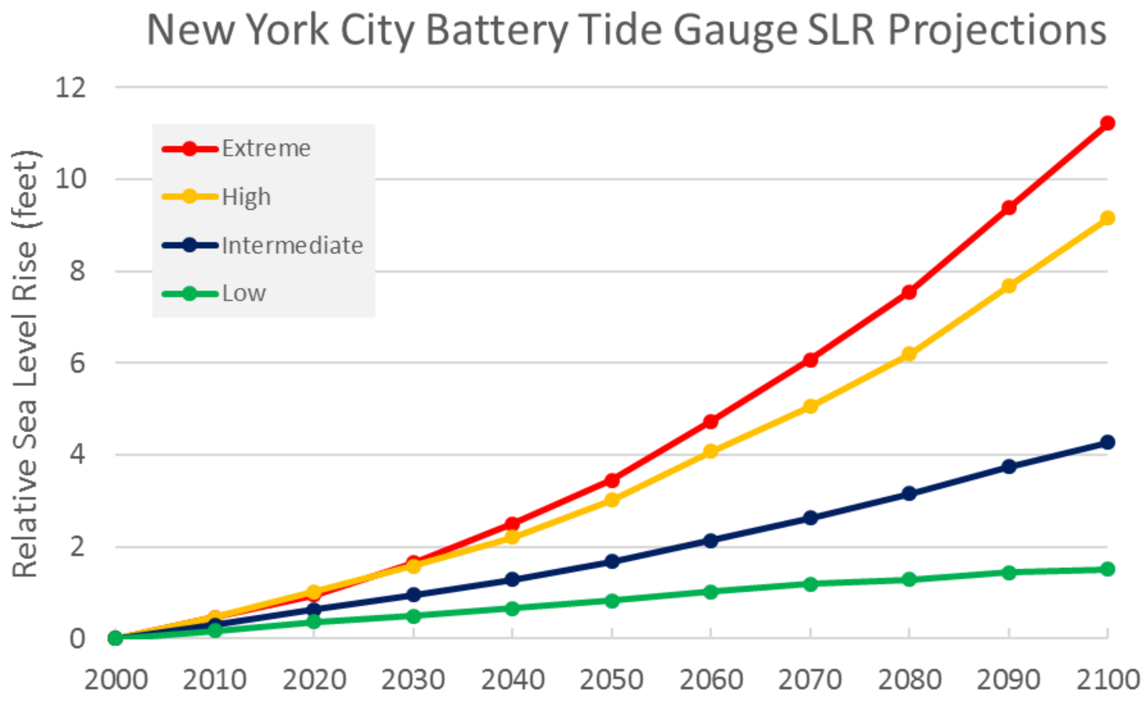
SEA LEVEL RISE: NOAA PROJECTIONS AND INUNDATION MAPS

WHAT SEA LEVEL RISE CAUSES FLOODING?

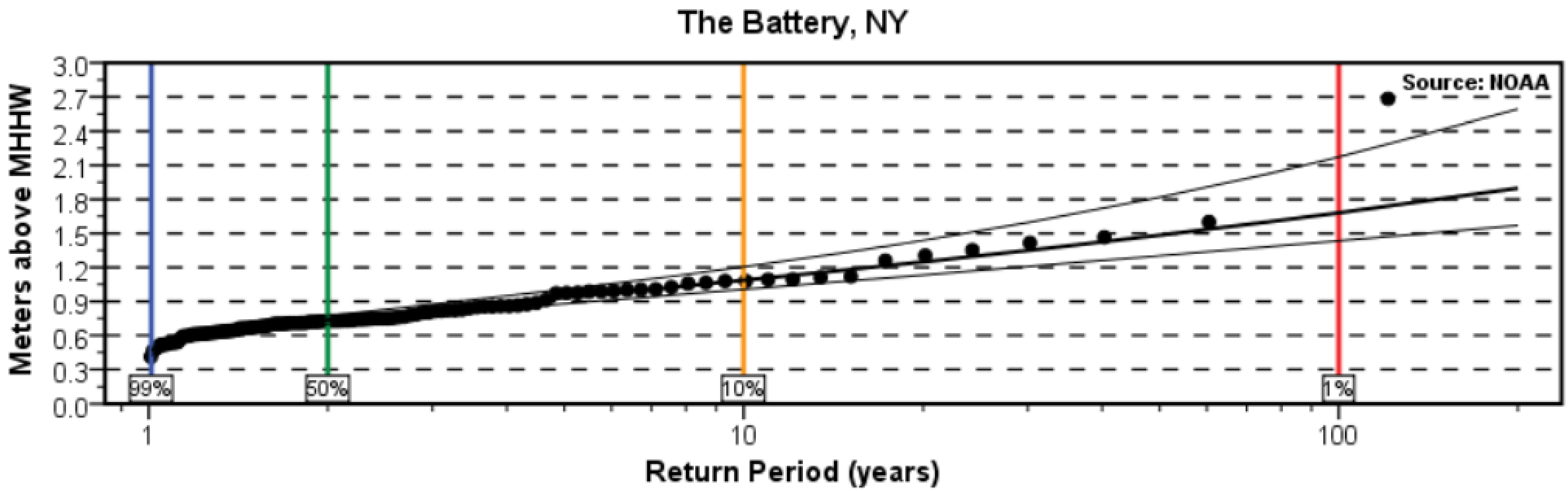
Sea Level Rise: 6 Feet



HOW HIGH WILL SEA LEVELS RISE AND WHEN?



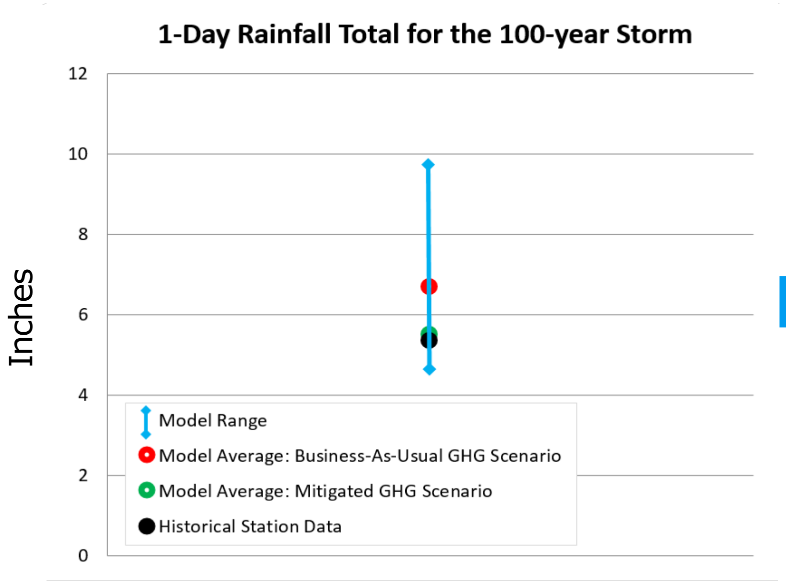
EXTREME COASTAL WATER LEVELS



- Future extreme water levels, considering a range of potential sea level rise
- Superimpose present-day storm surge levels and projected sea level rise
- Evaluate timing and severity of potential inundation - assess need for more detailed study

CLIMATE MODEL DATA GUIDES ADAPTATION MEASURE DESIGN

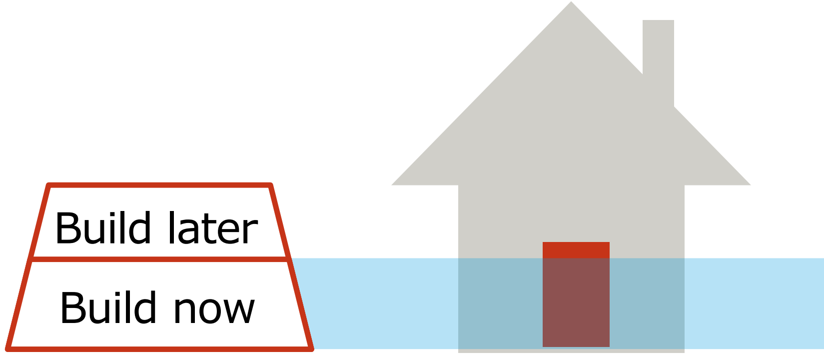
Climate Model Projections



Flood Risk Modelling

Design a Levee Protecting Houses

Levee for 100-year flood with climate change



- Levee width expanded to allow for lower cost upward extension in case higher projected future rainfall amounts begin to occur

INCORPORATING CHANGING EXTREMES INTO RISK ASSESSMENT AND RISK MANAGEMENT

01

Climate modeling of site to quantify projected changes in environmental conditions

02

Model impacts of projected climate change such as effect of future environmental conditions on containment structures

03

Revise design standards for impacted structures to account for projected future climate

04

Revise management plans to include provision of greater maintenance and monitoring and preparedness

05

Proactive, adaptive management approach enables incremental investment where possible

THANK YOU
QUESTIONS?

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