CLIMATE CHANGE IN VERMONT: BRIEFING #1

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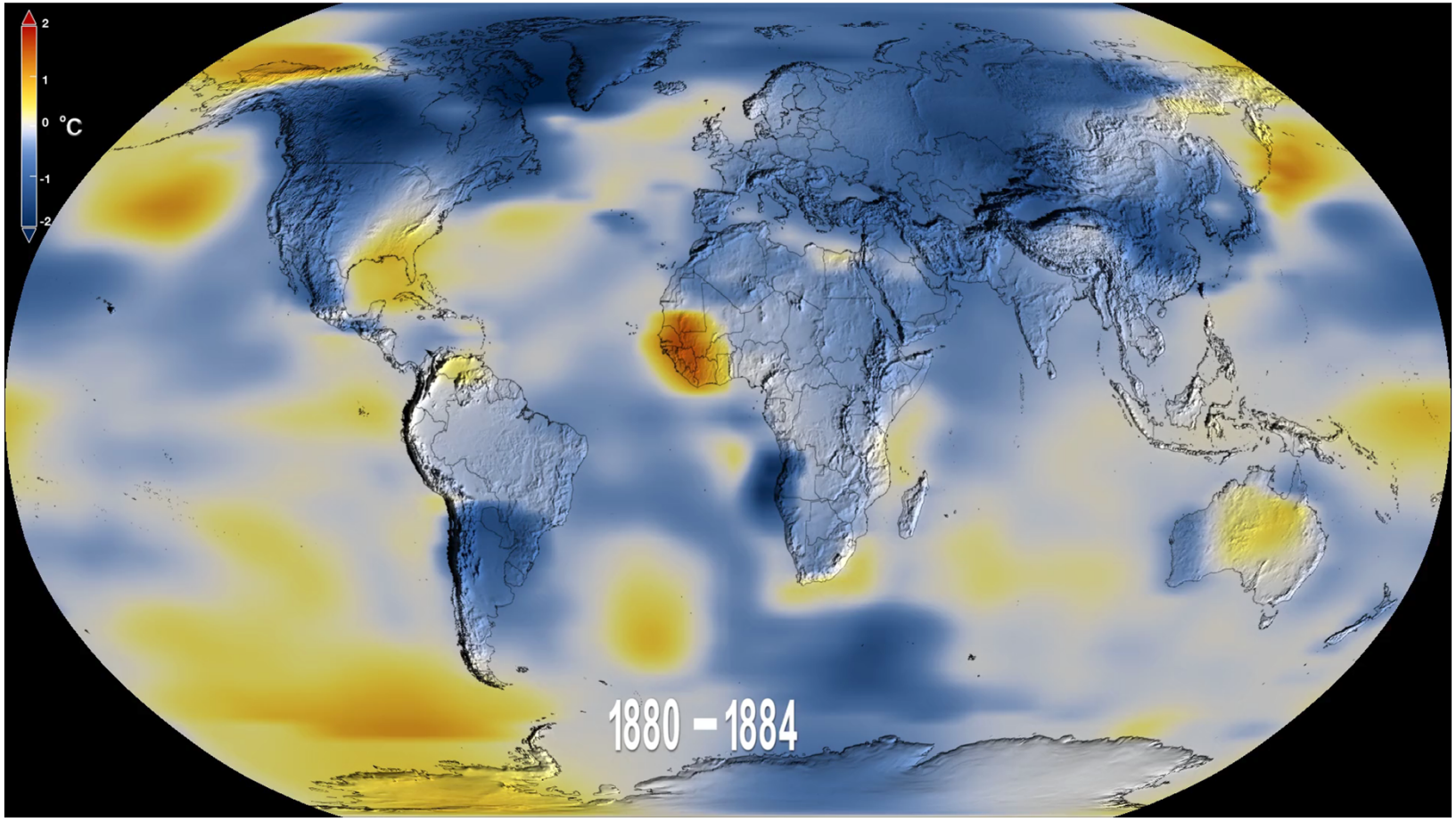
Vermont Climate Council – 21 December 2020

Outline

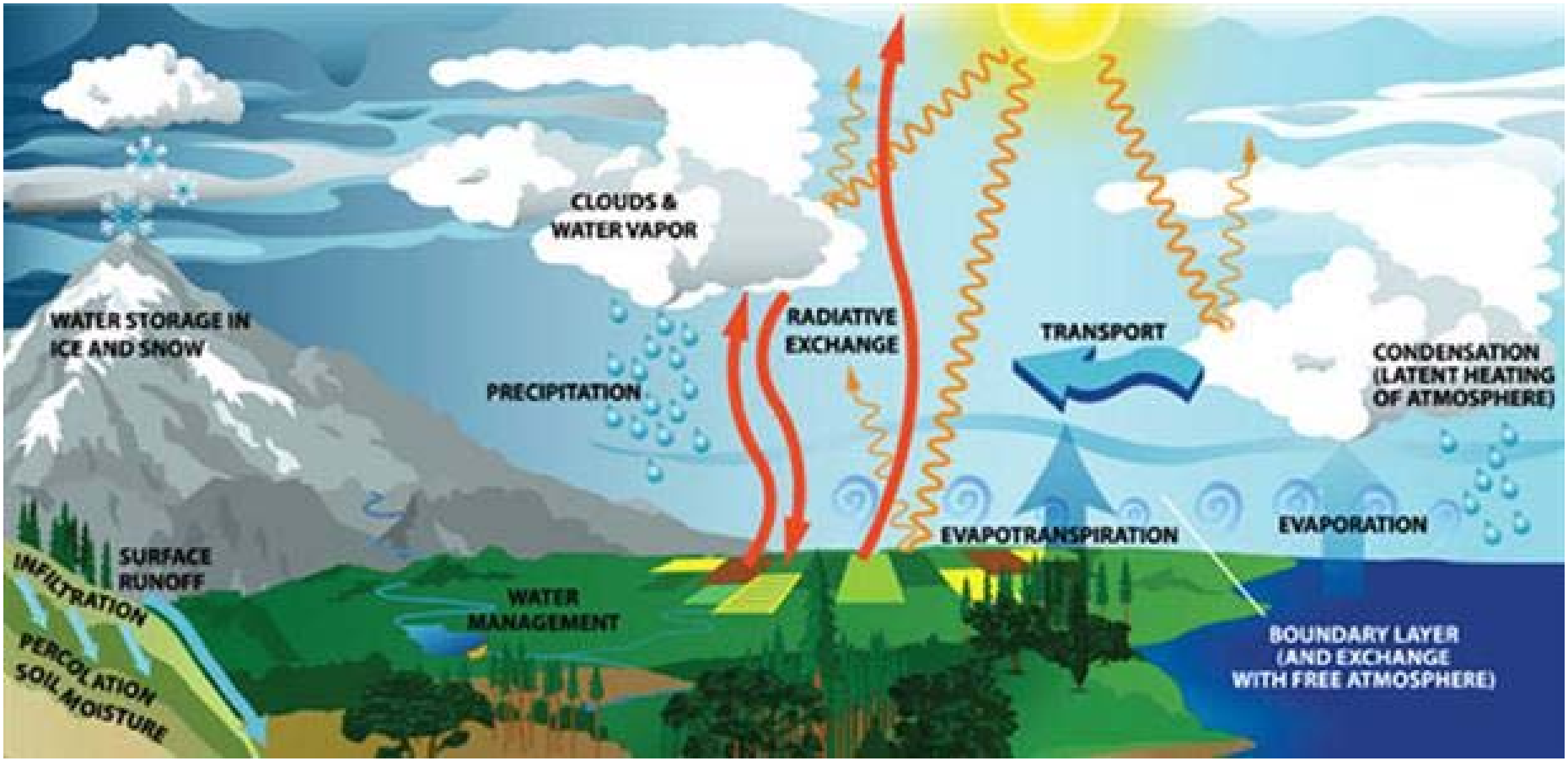
- Update to my testimony to the House Committee on Energy and Technology: H.688 (Global Warming Solutions Act) – 31 January 2020
- National Climate Assessment
- climate change in Vermont
- additional resources

Five-Year Average Global Temperature Anomalies from 1880 to 2019



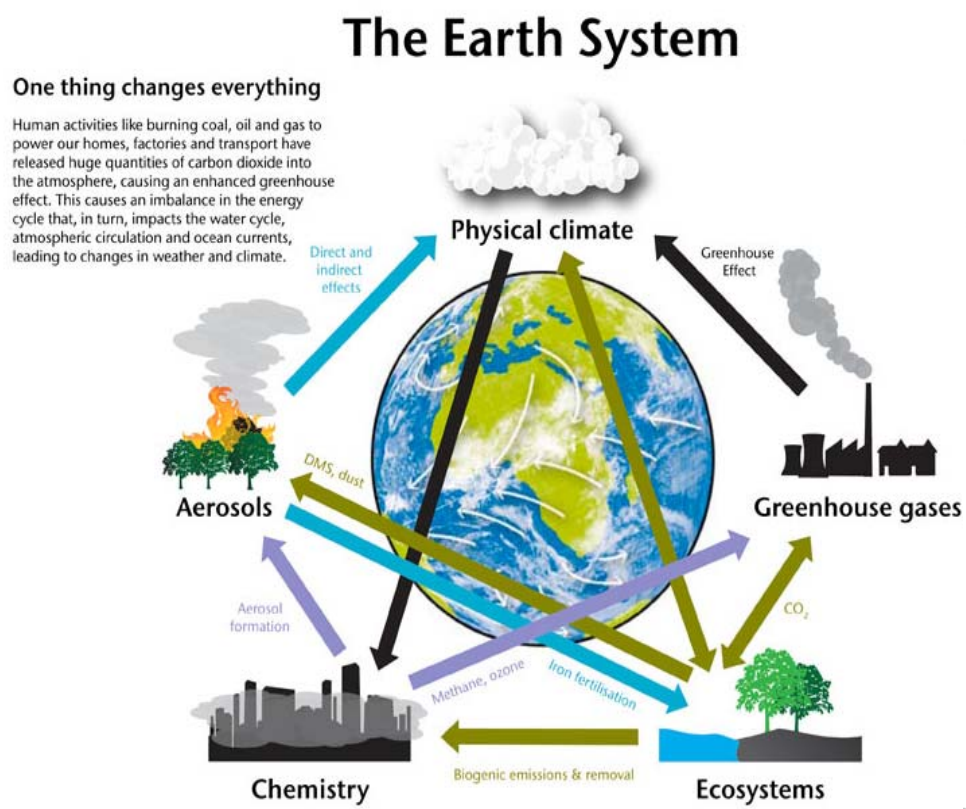
https://svs.gsfc.nasa.gov/4626

Climate is a system

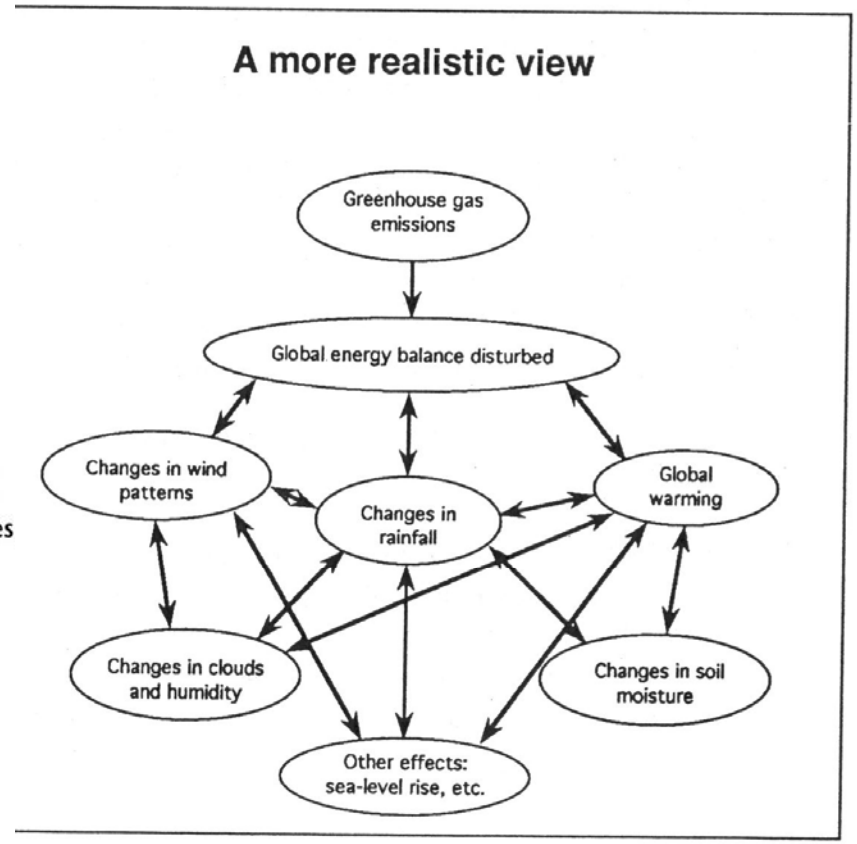


http://research.noaa.gov/sites/oar/EasyDNNNews/10430/620300c1768EDNmainearth_system_interactions.jpg

Climate change as a…system



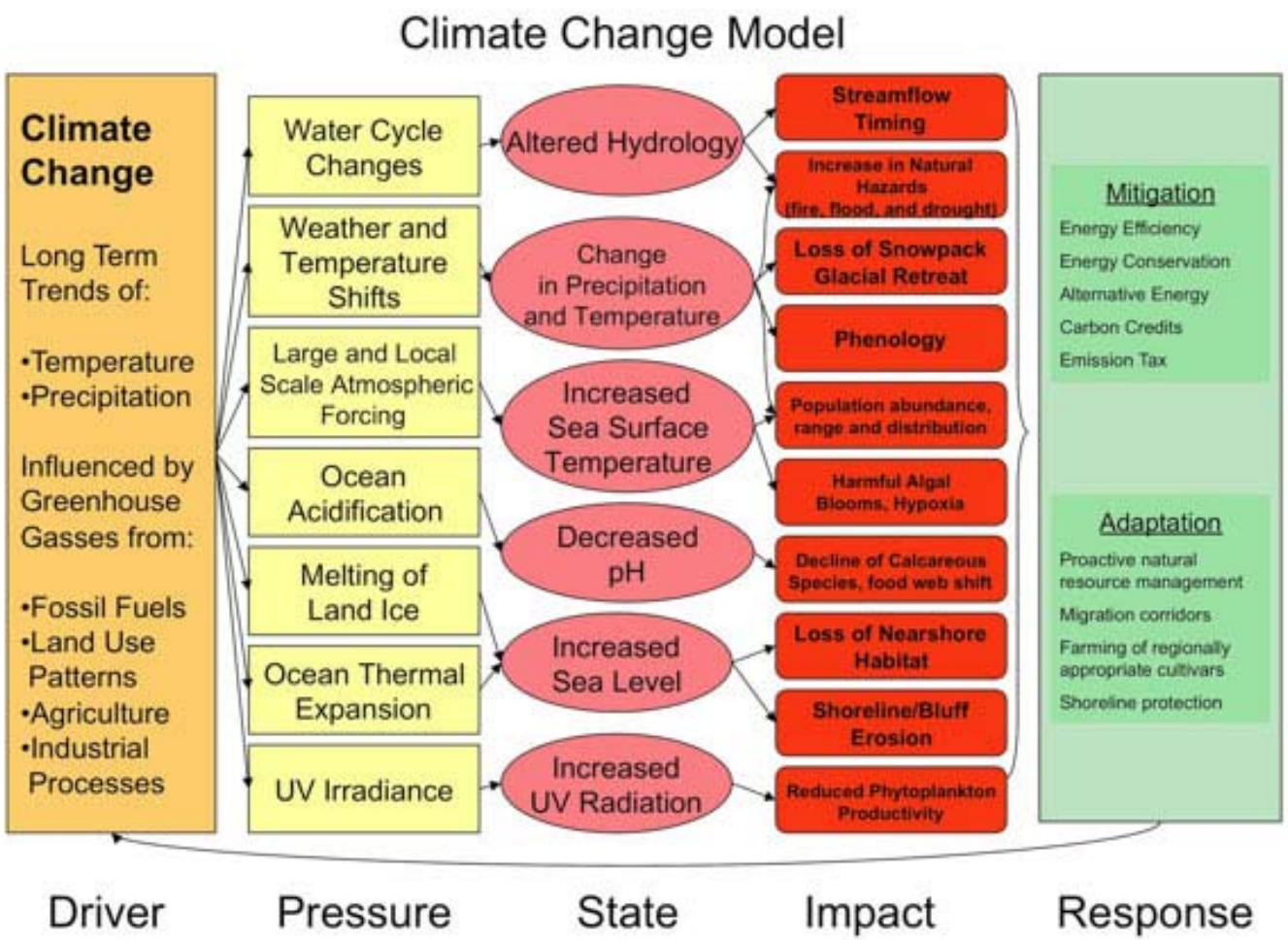
Schematic figure of HadGEM2-ES and the earth system interactions it represents



United Nations/UNEP

http://www.metoffice.gov.uk/research/news/cmip5

Process, impact, strategies



http://pugetsoundscienceupdate.com/pmwiki.php?n=Chapter3.Section2

Fourth National Climate Assessment (NCA4)

U.S. Global Change Research Program

Fourth National Climate Assessment, Vol II — Impacts, Risks, and Adaptation in the United States

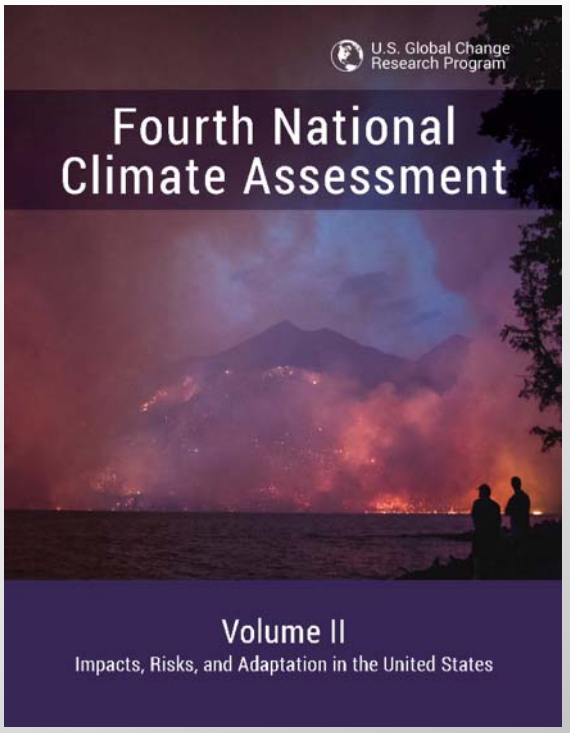
THE NATIONAL CLIMATE ASSESSMENT REPORT AND CLIMATE CHANGE IN VERMONT

DR. LESLEY-ANN L. DUPIGNY-GIROUX

UVM/VT STATE CLIMATOLOGIST/LEAD AUTHOR NCA4 NORTHEAST

NCA4 VOL II:
IMPACTS, RISKS, AND ADAPTATION IN THE U.S.

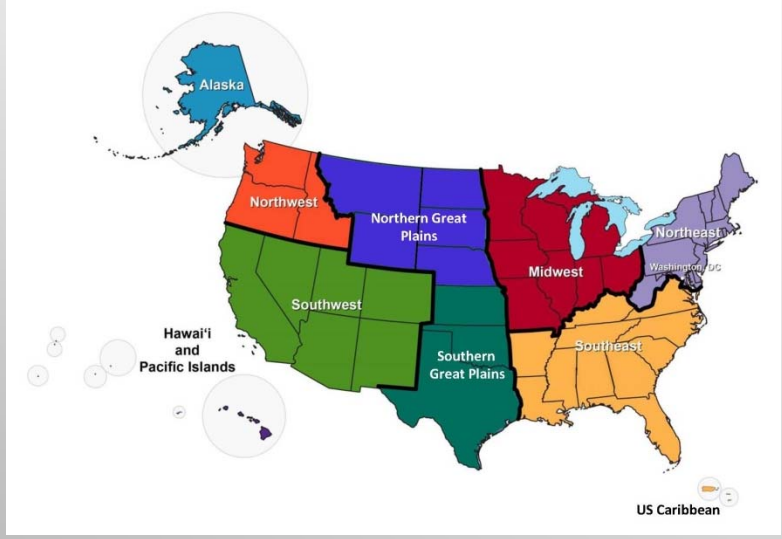
- POLICY RELEVANT, BUT NOT POLICY PRESCRIPTIVE
- PLACES A STRONG EMPHASIS ON REGIONAL INFORMATION
- ASSESSES A RANGE OF POTENTIAL IMPACTS, HELPING DECISION MAKERS BETTER IDENTIFY RISKS THAT COULD BE AVOIDED OR REDUCED
- USES CASE STUDIES TO PROVIDE ADDITIONAL CONTEXT AND OPPORTUNITIES TO SHOWCASE COMMUNITY SUCCESS STORIES



NCA4 Vol II is available at
nca2018.globalchange.gov

ADVANCES SINCE NCA3

- **EXPANDED REGIONAL FOCUS** IN RESPONSE TO GROWING DEMAND FOR LOCALIZED INFORMATION:
  - NEW CHAPTER DEDICATED TO THE U.S. CARIBBEAN, AND GREAT PLAINS DIVIDED INTO NORTHERN AND SOUTHERN REGIONS



Extreme weather events in Vermont can take the form of prolonged heavy snowstorms, flash floods, river floods (following snowmelt and heavy rains), severe thunderstorms, droughts, tornadoes, and temperature extremes. Some of the heaviest flooding in the state's history has been due to tropical cyclones or their remnants. In 2011, Tropical Storm Irene transitioned into an extratropical cyclone as it moved quickly northeastward along the Vermont/New Hampshire border. Roughly 3 to 7 inches of rain fell in less than 18 hours, causing the worst flooding in Vermont since the Great Flood of November 1927. Many rivers reached stages that were second to only the 1927 flood. The flooding resulted in an estimated $733 million in damage across the state.

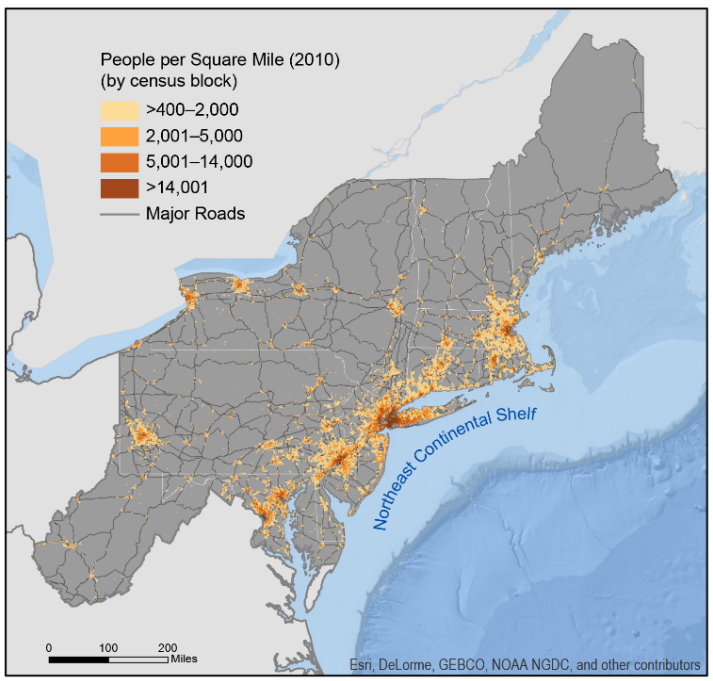
Severe winter storms are common in Vermont's cold winter climate and may include snowstorms, blizzards, and icing events. In addition to ice jams and melting snowpack as winter hazards, freezing rain and frozen ground conditions can also give rise to flooding. During the first week of January 1998, a prolonged storm brought 2 to 5 inches of rain to Vermont. Particularly across the Champlain Valley and parts of northern Vermont, temperatures were below freezing for much of the storm. This resulted in the "Great Ice Storm of '98" where heavy ice accumulations of 1 to 2 inches caused severe damage to trees and utility lines. Total damage from the ice storm across the whole of the northeastern United States was about $2 billion ($1.4 billion in 1998 dollars)

Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century (Figure 1). Even under a pathway of lower greenhouse gas emissions, average annual temperatures are projected to most likely exceed historical record levels by the middle of the 21st century. However, there is a large range of temperature increases under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records (Figure 1). Increases in the number of hot days and decreases in the number of very cold nights are projected to accompany the overall warming.

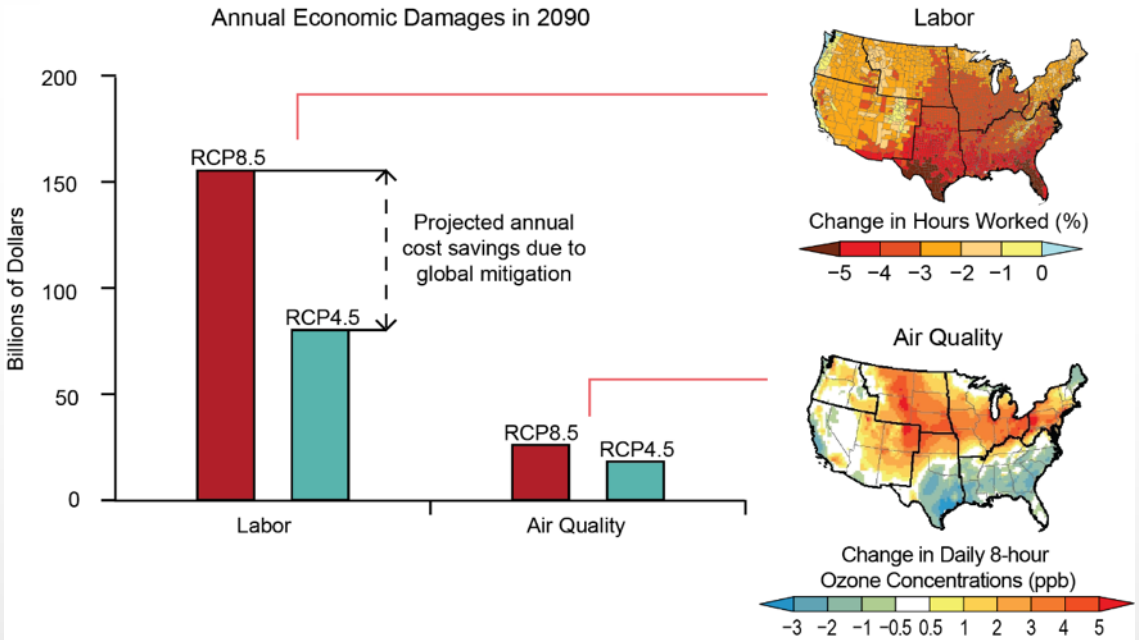
Average annual precipitation is projected to increase in Vermont over the 21st century, particularly during winter and spring (Figure 5). Corresponding increases in temperature will increase the proportion of precipitation falling as rain rather than snow. In addition, extreme precipitation is projected to increase, potentially increasing the frequency and intensity of floods.

OTHER NEW ELEMENTS OF NCA4

- PRODUCTS DEVELOPED
  - ECONOMIC VALUATION STUDIES & WHERE POSSIBLE:
    - QUANTIFICATION OF CLIMATE CHANGE IMPACTS IN ECONOMIC TERMS UNDER DIFFERENT FUTURE GREENHOUSE GAS EMISSIONS SCENARIOS
    - DOES NOT YET CHARACTERIZE DIFFERENTIAL ECONOMIC IMPACTS FOR ALL 10 NCA REGIONS
    - PROVIDES AN INDICATION OF THE POTENTIAL FOR REDUCING RISKS THROUGH MITIGATION ACTIONS
  - CLIMATE CHANGE INDICATORS
  - LOCA DOWNSCALED PRODUCTS
- UNIQUE FEATURES EACH REGION
  - E.G. NORTHEAST
    - RURAL/URBAN
    - INLAND/COASTAL
    - CULTURAL HERITAGE
    - LENGTH OF SETTLEMENT
    - PHYSICAL GEOGRAPHY/TOPOGRAPHY



NEW ECONOMIC IMPACT STUDIES



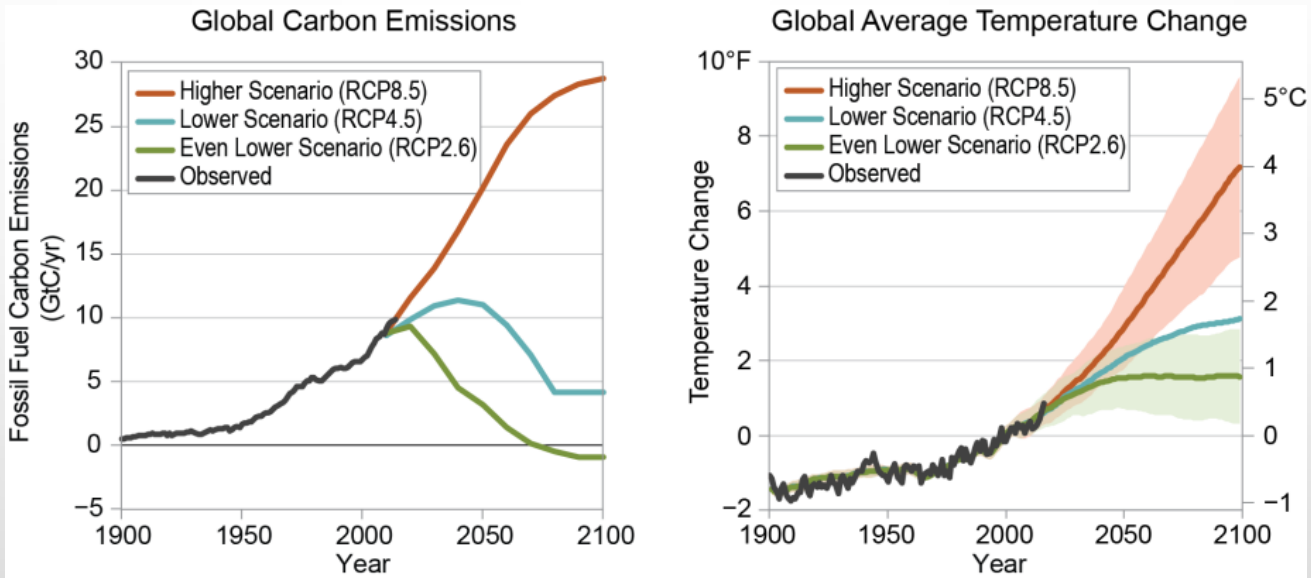
Source: EPA, 2017. Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment. U.S. Environmental Protection Agency, EPA 430-R-17-001.

ANNUAL ECONOMIC IMPACT ESTIMATES ARE SHOWN FOR LABOR AND AIR QUALITY. ***(LEFT)*** NATIONAL ANNUAL DAMAGES IN 2090 FOR A HIGHER SCENARIO AND LOWER SCENARIO; THE DIFFERENCE BETWEEN THE HEIGHT OF THE RED AND TEAL BARS FOR A GIVEN CATEGORY REPRESENTS AN ESTIMATE OF THE ECONOMIC BENEFIT TO THE U.S. FROM GLOBAL MITIGATION ACTION.

(RIGHT) REGIONAL VARIATION IN ANNUAL IMPACTS PROJECTED UNDER THE HIGHER SCENARIO IN 2090. THE MAP ON THE TOP SHOWS THE PERCENT CHANGE IN HOURS WORKED IN HIGH-RISK INDUSTRIES AS COMPARED TO THE PERIOD 2003–2007. THE MAP ON THE BOTTOM IS THE CHANGE IN GROUND-LEVEL OZONE CONCENTRATIONS COMPARED TO THE PERIOD 1995–2005.

Sidebar – RCPs & COVID-19

REPRESENTATIVE CONCENTRATION PATHWAYS (RCP)

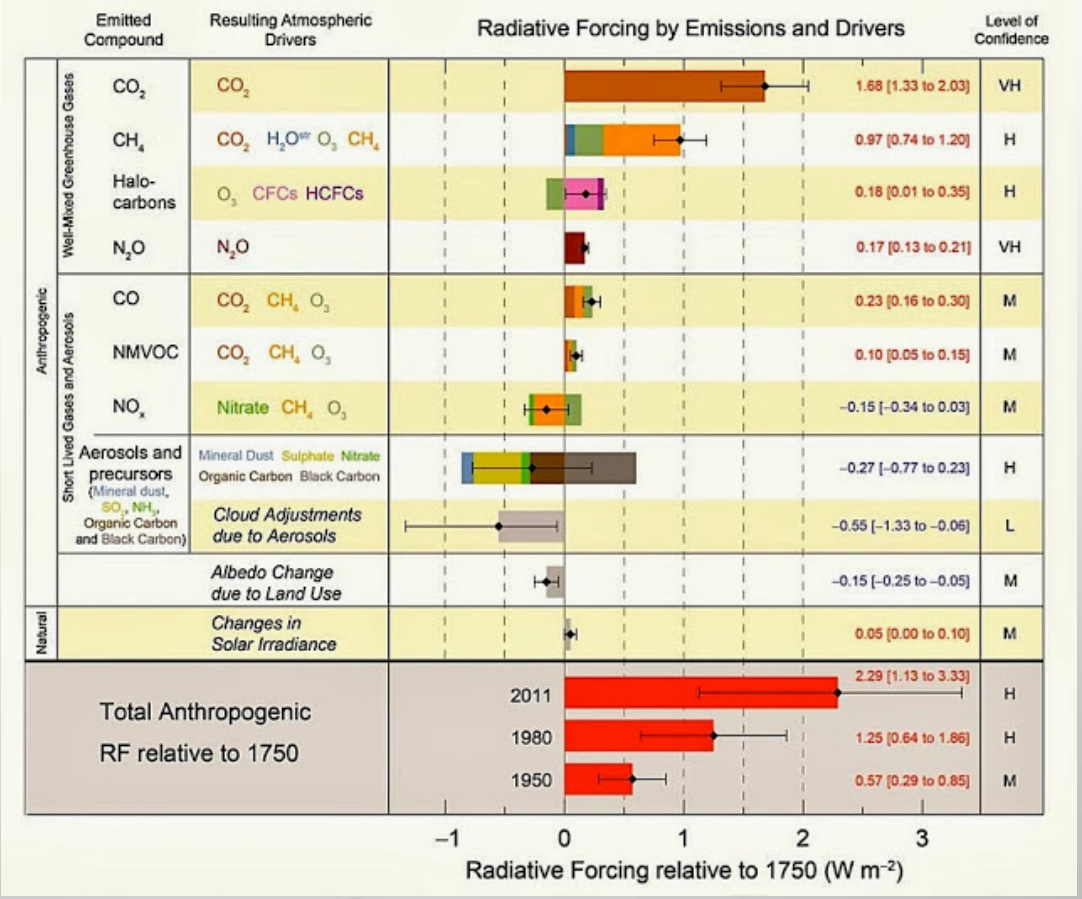


Projections of future changes in climate are based on scenarios of greenhouse gas emissions and other pollutants from human activities. The primary scenarios used in this assessment are called Representative Concentration Pathways (RCPs)[219] and are numbered according to changes in radiative forcing (a measure of the influence that a factor, such as greenhouse gas emissions, has in changing the global balance of incoming and outgoing energy) in 2100 relative to preindustrial conditions: +2.6 (very low), +4.5 (lower), +6.0 (mid-high) and +8.5 (higher) watts per square meter (W/m^2). Some scenarios are consistent with increasing dependence on fossil fuels, while others could only be achieved by deliberate actions to reduce emissions (see Section 4.2 in Hayhoe et al. 2017[24] for more details). The resulting range in forcing scenarios reflects the uncertainty inherent in quantifying human activities and their influence on climate (e.g., Hawkins and Sutton 2009, 2011[23,220]).

http://www.climatechange2013.org/images/figures/WGI_AR5_FigSPM-5.jpg

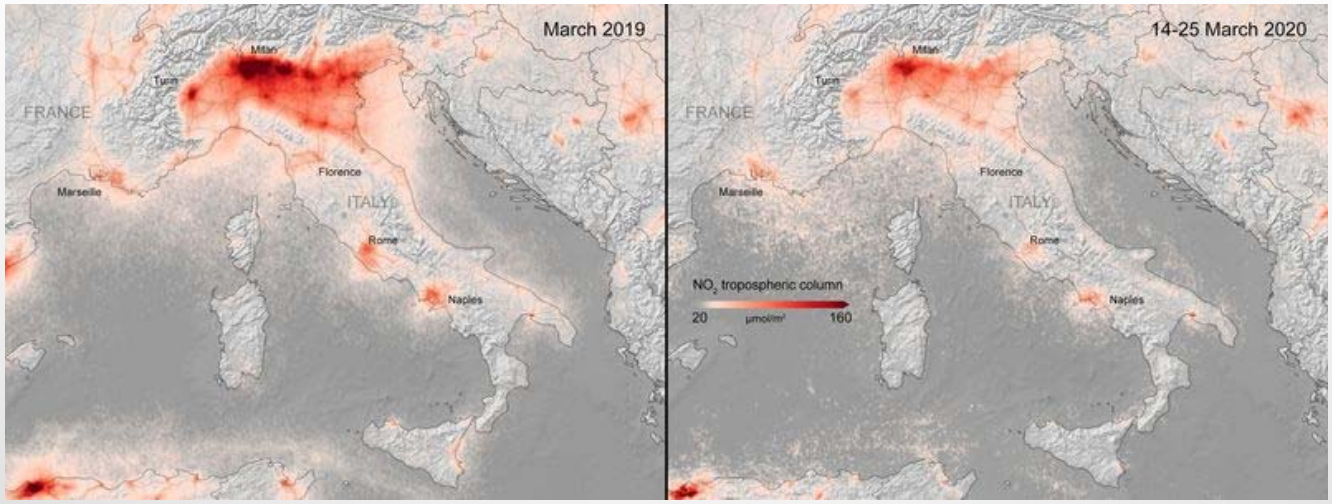
GREENHOUSE GASES – INFLUENCE ON THE ATMOSPHERE

- CARBON DIOXIDE
- NITROGEN DIOXIDE



https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Coronavirus_lockdown_leading_to_drop_in_pollution_across_Europe

COMPARISONS IN NITROGEN DIOXIDE MARCH 2019 & MARCH 2020



Copernicus Sentinel-5P satellite
ESA

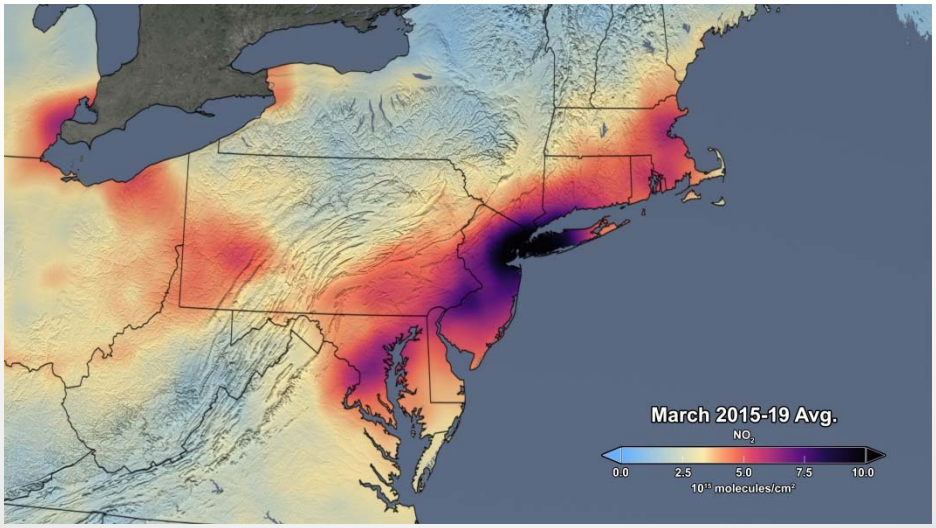
- "AS NITROGEN DIOXIDE IS PRIMARILY PRODUCED BY TRAFFIC AND FACTORIES, IT IS A FIRST-LEVEL INDICATOR OF INDUSTRIAL ACTIVITY WORLDWIDE." JOSEF ASCHBACHER, ESA'S DIRECTOR OF EARTH OBSERVATION PROGRAMMES
- DAILY FLUCTUATIONS IN CONCENTRATION DUE TO WEATHER
- "GROUND DATA, WEATHER DATA AND INVERSE MODELLING TO INTERPRET THE CONCENTRATIONS OBSERVED" HENK ESKES, KNMI

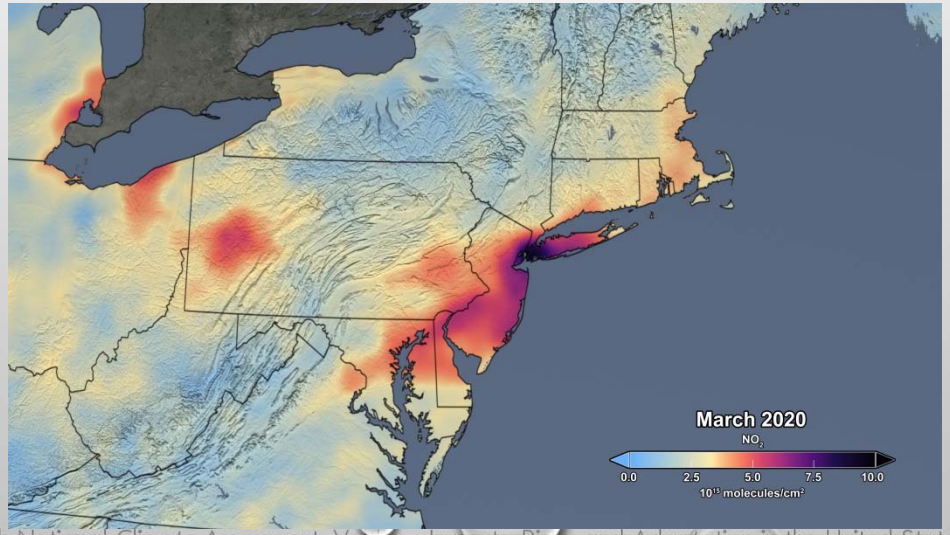
April 9, 2020

https://www.nasa.gov/feature/goddard/2020/drop-in-air-pollution-over-northeast

NASA Satellite Data Show 30 Percent Drop In Air Pollution Over Northeast U.S.

Over the past several weeks, NASA satellite measurements have revealed significant reductions in air pollution over the major metropolitan areas of the Northeast United States. Similar reductions have been observed in other regions of the world. These recent improvements in air quality have come at a high cost, as communities grapple with widespread lockdowns and shelter-in-place orders as a result of the spread of COVID-19.





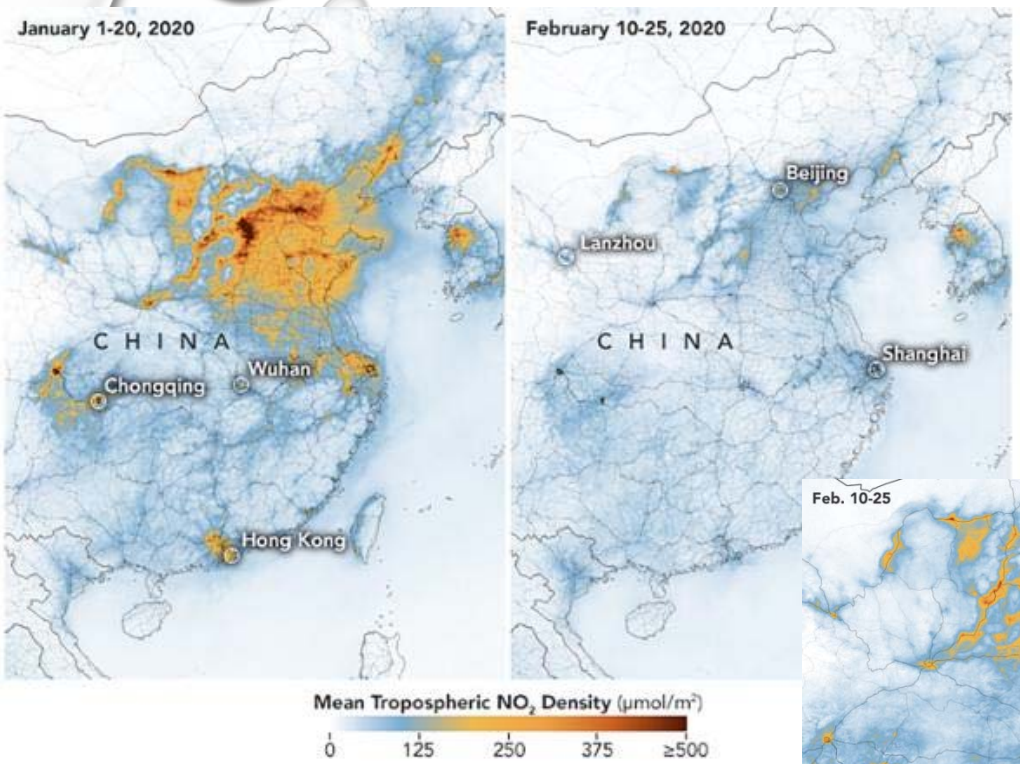
"March 2020 shows the lowest monthly atmospheric nitrogen dioxide levels of any March during the OMI data record, which spans 2005 to the present. In fact, the data indicate that the nitrogen dioxide levels in March 2020 are about 30% lower on average across the region of the I-95 corridor from Washington, DC to Boston than when compared to the March mean of 2015-19. Further analysis will be required to rigorously quantify the amount of the change in nitrogen dioxide levels associated with changes in emissions versus natural variations in weather."

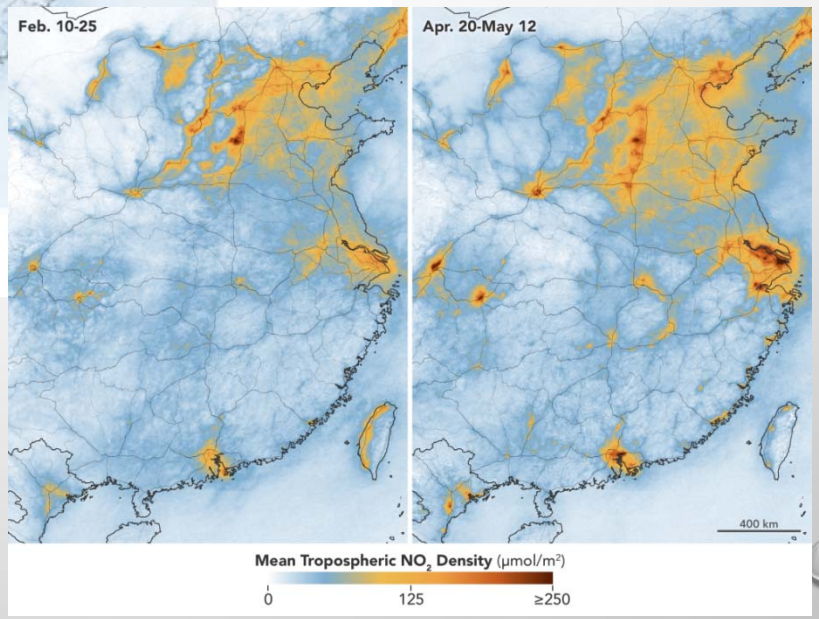
Courtesy: NASA OMI

U.S. Global Change Research Program

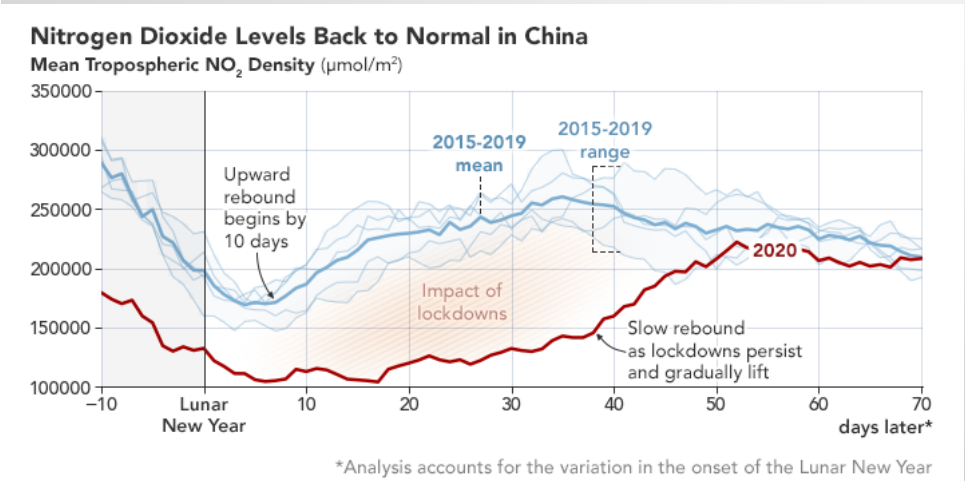
Fourth National Climate Assessment, Vol. II — Impacts, Risks, and Adaptation in the United States
nca2018.globalchange.gov

https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/COVID-19_nitrogen_dioxide_over_China



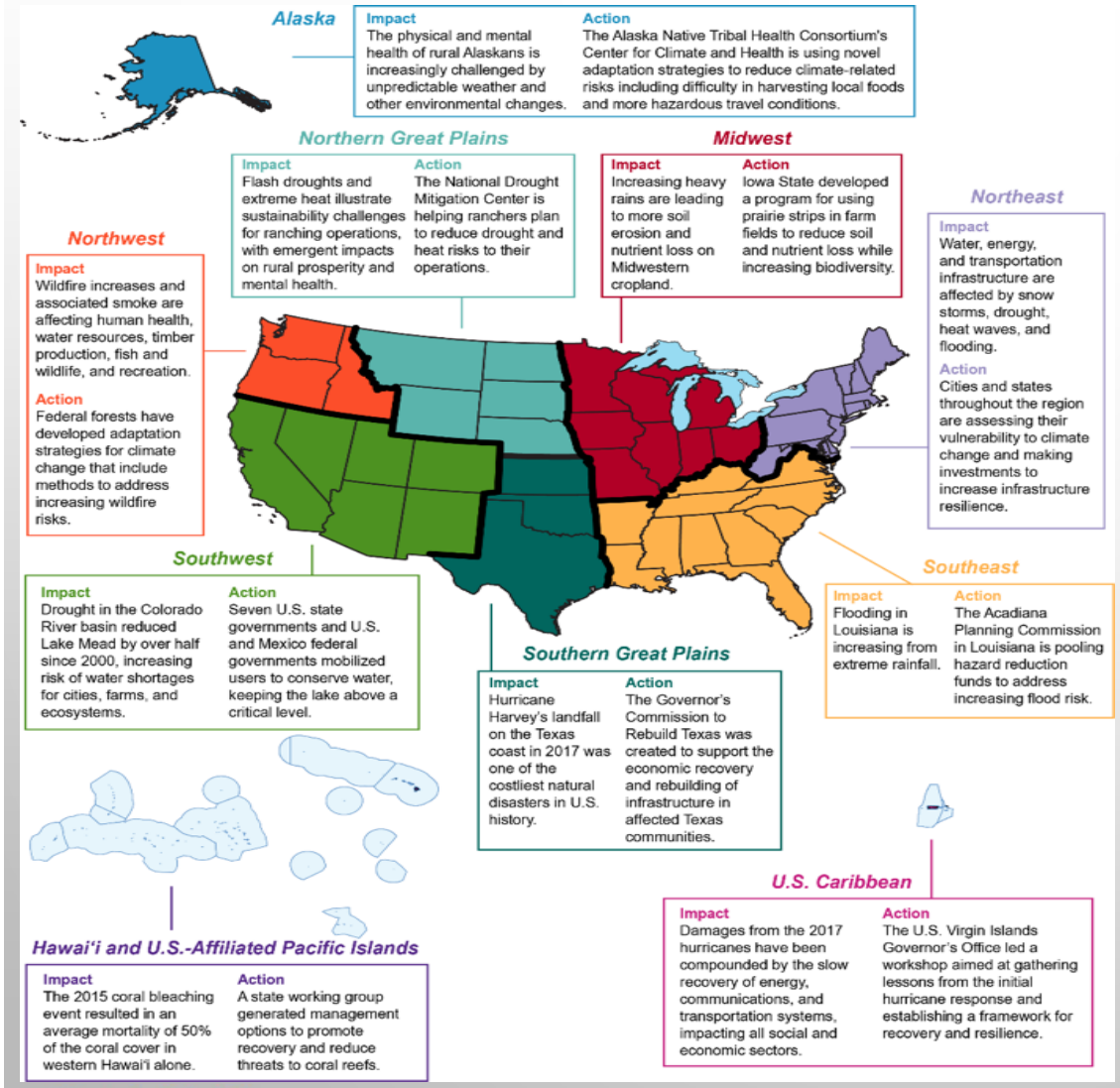


https://earthobservatory.nasa.gov/images/146741/nitrogen-dioxide-levels-rebound-in-china



NCA4 - highlights

AMERICANS RESPOND TO THE IMPACTS OF CLIMATE CHANGE



- THIS MAP SHOWS CLIMATE-RELATED IMPACTS THAT HAVE OCCURRED IN EACH REGION SINCE THE THIRD NATIONAL CLIMATE ASSESSMENT IN 2014 AND RESPONSE ACTIONS THAT ARE HELPING THE REGION ADDRESS RELATED RISKS AND COSTS. THESE EXAMPLES ARE ILLUSTRATIVE; THEY ARE NOT INDICATIVE OF WHICH IMPACT IS MOST SIGNIFICANT IN EACH REGION OR WHICH RESPONSE ACTION MIGHT BE MOST EFFECTIVE. *SOURCE: NCA4 REGIONAL CHAPTERS.*

OVERARCHING THEMES

- ECOSYSTEMS AND ECOSYSTEM SERVICES
- SEA LEVEL RISE
- MARINE & COASTAL RESOURCES
- HUMAN HEALTH
- INDIGENOUS PEOPLES
- RURAL COMMUNITIES & THEIR LIVELIHOODS
- ADAPTATION & ADAPTIVE CAPACITY
- AGRICULTURAL PRODUCTIVITY
- INFRASTRUCTURE & TRANSPORTATION

18 KEY MESSAGE #1

CHANGING SEASONS AFFECT RURAL ECOSYSTEMS, ENVIRONMENTS, AND ECONOMIES

THE SEASONALITY OF THE NORTHEAST IS CENTRAL TO THE REGION'S SENSE OF PLACE AND IS AN IMPORTANT DRIVER OF RURAL ECONOMIES. LESS DISTINCT SEASONS WITH MILDER WINTER AND EARLIER SPRING CONDITIONS ARE ALREADY ALTERING ECOSYSTEMS AND ENVIRONMENTS IN WAYS THAT ADVERSELY IMPACT TOURISM, FARMING, AND FORESTRY. THE REGION'S RURAL INDUSTRIES AND LIVELIHOODS ARE AT RISK FROM FURTHER CHANGES TO FORESTS, WILDLIFE, SNOWPACK, AND STREAMFLOW.

FIG. 18.1: POPULATION DENSITY

A SATELLITE MOSAIC OVERLAID WITH PRIMARY ROADS AND POPULATION DENSITY HIGHLIGHTS THE DIVERSE CHARACTERISTICS OF THE REGION IN TERMS OF SETTLEMENT PATTERNS, INTERCONNECTIONS AMONG POPULATION CENTERS OF VARYING SIZES, AND VARIABILITY IN RELIEF ACROSS THE OCEAN SHELF. *SOURCES: U.S. DEPARTMENT OF TRANSPORTATION, U.S. GEOLOGICAL SURVEY, AND ERT, INC.*

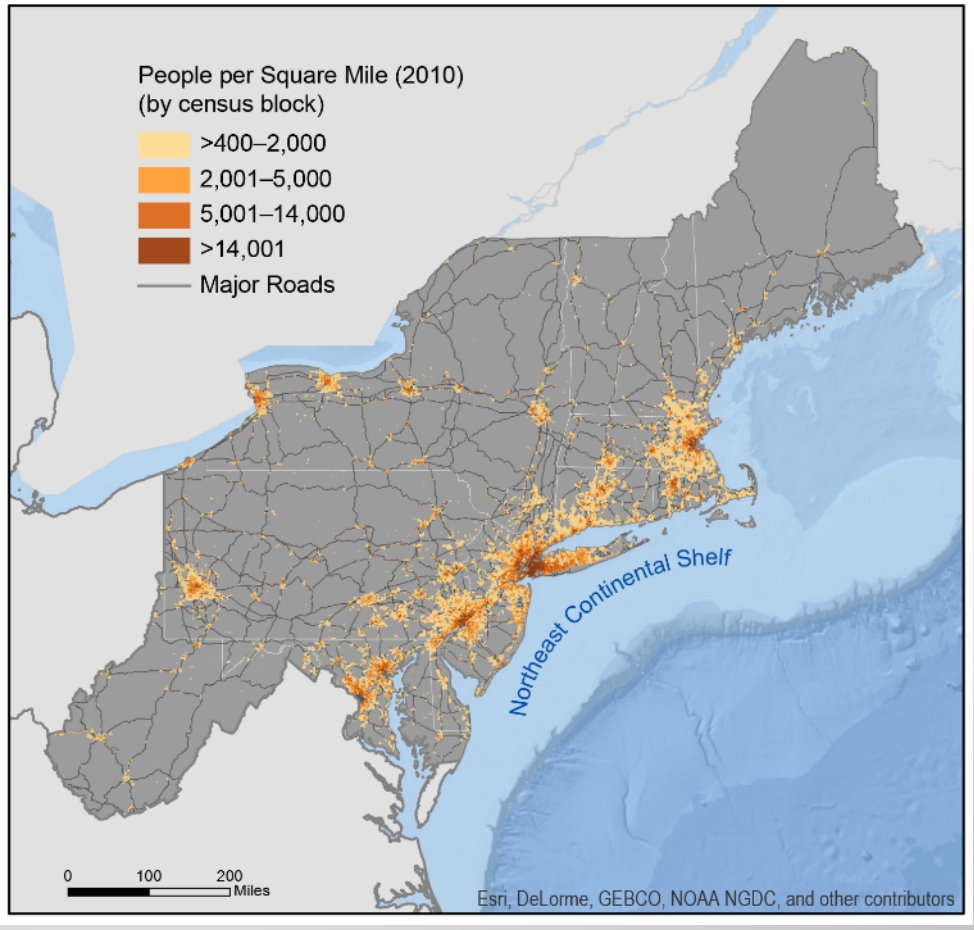
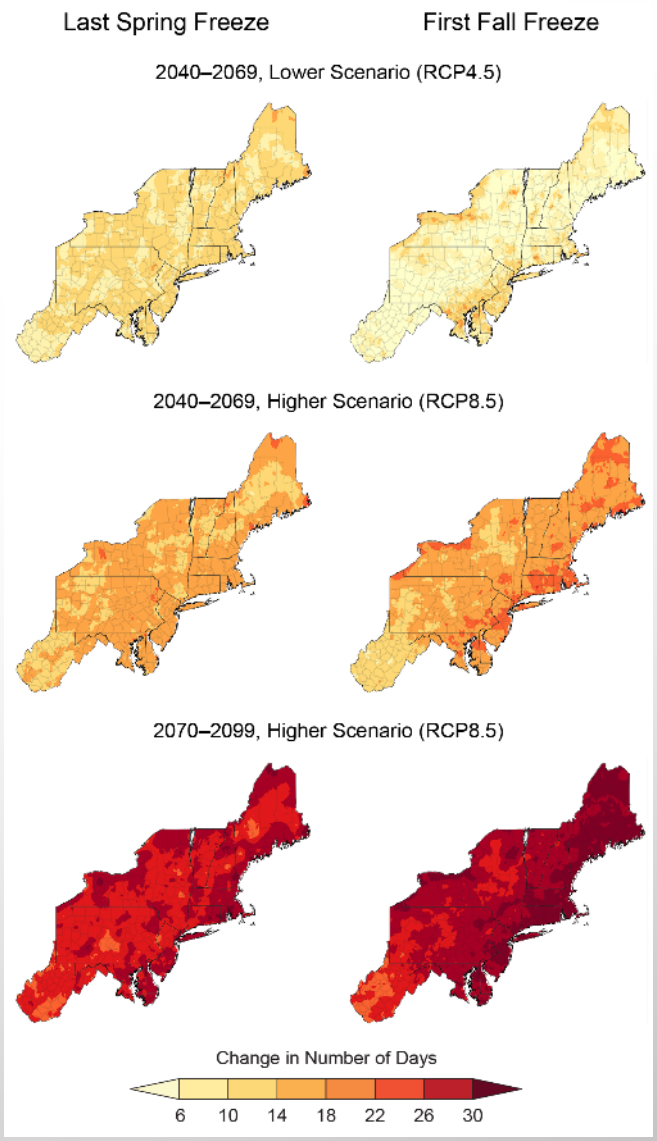


FIG. 18.3: LENGTHENING OF THE FREEZE-FREE PERIOD

THESE MAPS SHOW PROJECTED SHIFTS IN THE DATE OF THE LAST SPRING FREEZE (LEFT COLUMN) AND THE DATE OF THE FIRST FALL FREEZE (RIGHT COLUMN) FOR THE MIDDLE OF THE CENTURY (AS COMPARED TO 1979–2008) UNDER THE LOWER SCENARIO (RCP4.5; TOP ROW) AND THE HIGHER SCENARIO (RCP8.5; MIDDLE ROW). THE BOTTOM ROW SHOWS THE SHIFT IN THESE DATES FOR THE END OF THE CENTURY UNDER THE HIGHER SCENARIO. BY THE MIDDLE OF THE CENTURY, THE FREEZE-FREE PERIOD ACROSS MUCH OF THE NORTHEAST IS EXPECTED TO LENGTHEN BY AS MUCH AS TWO WEEKS UNDER THE LOWER SCENARIO AND BY TWO TO THREE WEEKS UNDER THE HIGHER SCENARIO. BY THE END OF THE CENTURY, THE FREEZE-FREE PERIOD IS EXPECTED TO INCREASE BY AT LEAST THREE WEEKS OVER MOST OF THE REGION. *SOURCE: ADAPTED FROM WOLFE ET AL. 2018.*[35]



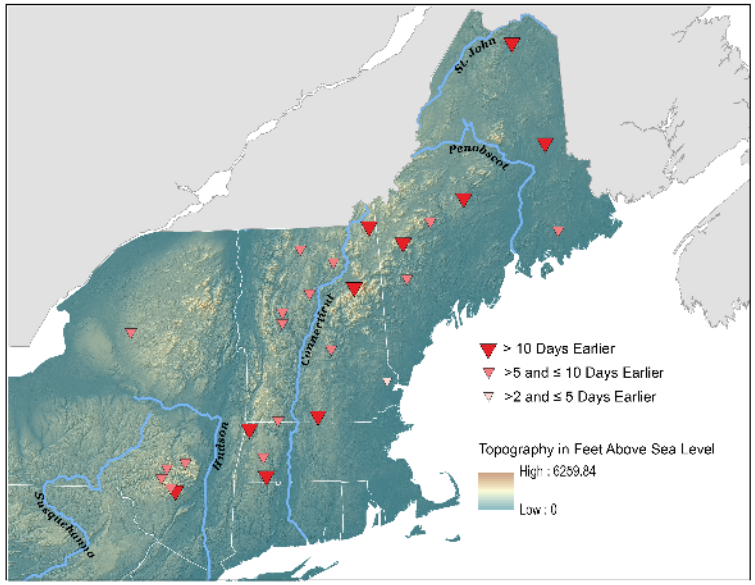
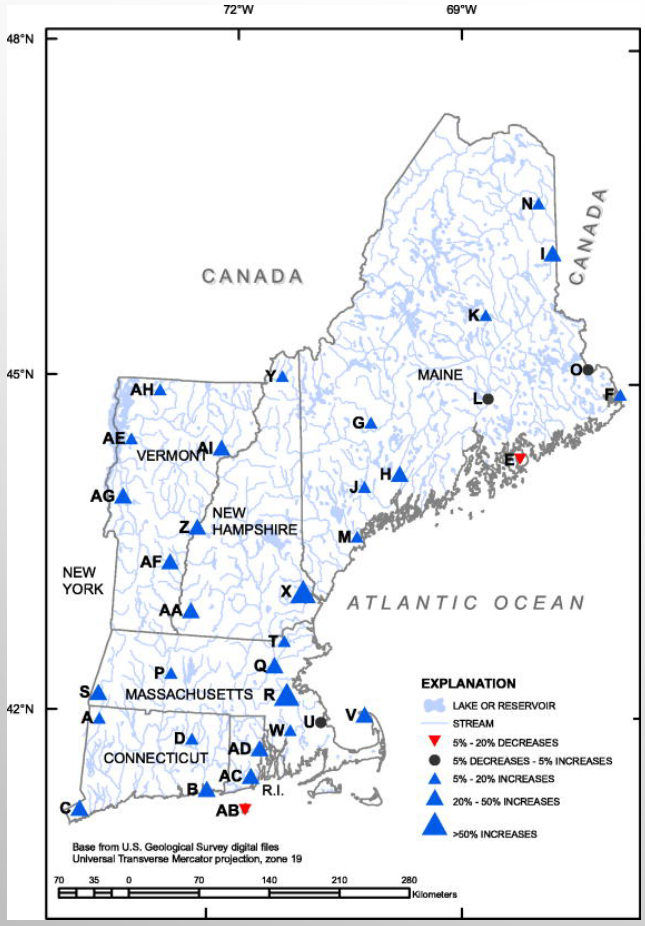


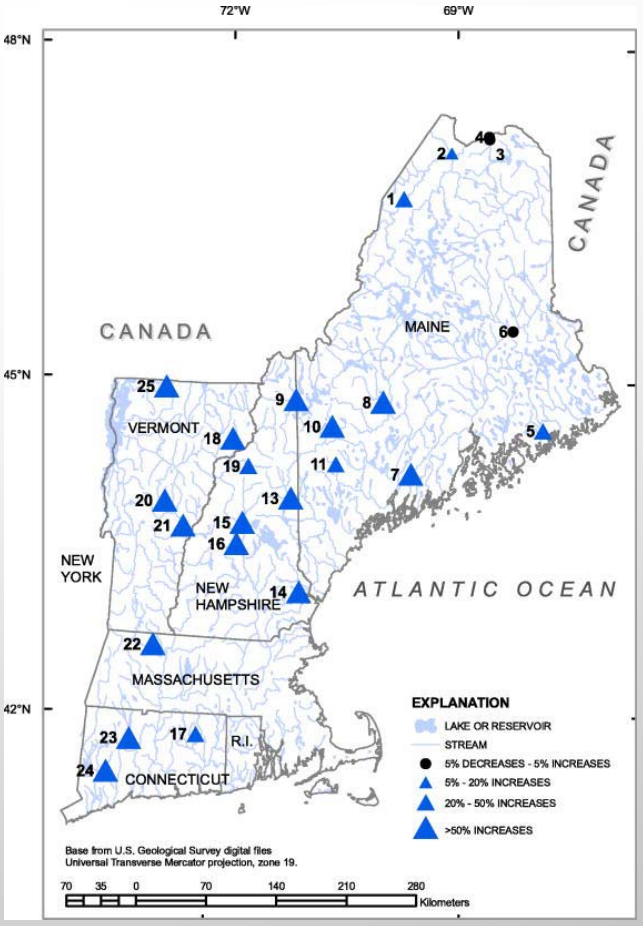
FIG. 18.2: HISTORICAL CHANGES IN THE TIMING OF SNOWMELT-RELATED STREAMFLOW

THIS MAP OF PART OF THE NORTHEAST REGION SHOWS CONSISTENTLY EARLIER SNOWMELT-RELATED STREAMFLOW TIMING FOR RIVERS FROM 1960 TO 2014. EACH SYMBOL REPRESENTS THE CHANGE FOR AN INDIVIDUAL RIVER OVER THE ENTIRE PERIOD. CHANGES IN THE TIMING OF SNOWMELT POTENTIALLY INTERFERE WITH THE REPRODUCTION OF MANY AQUATIC SPECIES[113] AND IMPACT WATER-SUPPLY RESERVOIR MANAGEMENT BECAUSE OF HIGHER WINTER FLOWS AND LOWER SPRING FLOWS.[114] THE TIMING OF SNOWMELT-RELATED STREAMFLOW IN THE NORTHEAST IS SENSITIVE TO SMALL CHANGES IN AIR TEMPERATURE. THE AVERAGE WINTER–SPRING AIR TEMPERATURE INCREASE OF 1.67°F IN THE NORTHEAST FROM 1940 TO 2014 IS THOUGHT TO BE THE CAUSE OF AVERAGE EARLIER STREAMFLOW TIMING OF 7.7 DAYS.[112] THE TIMING OF SNOWMELT-RELATED STREAMFLOW IS A VALUABLE LONG-TERM INDICATOR OF WINTER–SPRING CHANGES IN THE NORTHEAST. *SOURCE: ADAPTED FROM DUDLEY ET AL. 2017;*[112] *DIGITAL ELEVATION MODEL CGIAR–CSI (CGIAR CONSORTIUM FOR SPATIAL INFORMATION). REPRINTED WITH PERMISSION FROM ELSEVIER.*

SUMMER CHANGES – 1950-2006

PRECIP





STORMFLOW

Hodgkins & Dudley, Water Resources Research, Volume: 47, Issue: 7, First published: 15 July 2011, DOI: (10.1029/2010WR009109)

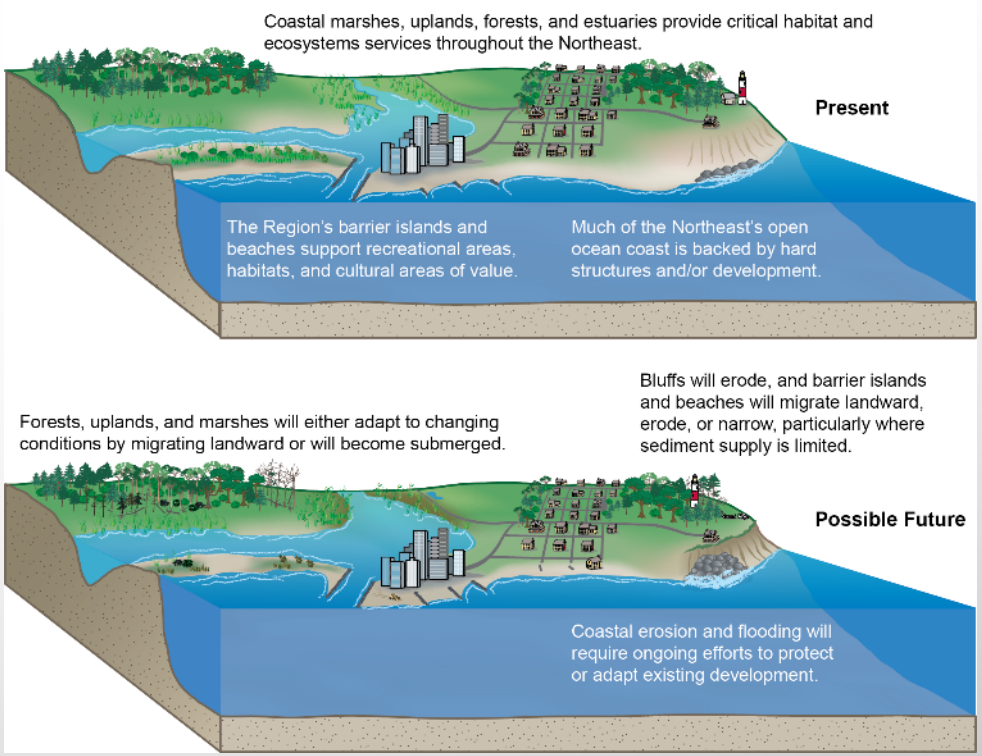
18 KEY MESSAGE #2

CHANGING COASTAL AND OCEAN HABITATS, ECOSYSTEM SERVICES, AND LIVELIHOODS

THE NORTHEAST'S COAST AND OCEAN SUPPORT COMMERCE, TOURISM, AND RECREATION THAT ARE IMPORTANT TO THE REGION'S ECONOMY AND WAY OF LIFE. WARMER OCEAN TEMPERATURES, SEA LEVEL RISE, AND OCEAN ACIDIFICATION THREATEN THESE SERVICES. THE ADAPTIVE CAPACITY OF MARINE ECOSYSTEMS AND COASTAL COMMUNITIES WILL INFLUENCE ECOLOGICAL AND SOCIOECONOMIC OUTCOMES AS CLIMATE RISKS INCREASE.

FIG 18.7: COASTAL IMPACTS OF CLIMATE CHANGE

(TOP) THE NORTHEASTERN COASTAL LANDSCAPE IS COMPOSED OF UPLANDS AND FORESTED AREAS, WETLANDS AND ESTUARINE SYSTEMS, MAINLAND AND BARRIER BEACHES, BLUFFS, HEADLANDS, AND ROCKY SHORES, AS WELL AS DEVELOPED AREAS, ALL OF WHICH PROVIDE A VARIETY OF IMPORTANT SERVICES TO PEOPLE AND SPECIES. (BOTTOM) FUTURE IMPACTS FROM INTENSE STORM ACTIVITY AND SEA LEVEL RISE WILL VARY ACROSS THE LANDSCAPE, REQUIRING A VARIETY OF ADAPTATION STRATEGIES IF PEOPLE, HABITATS, TRADITIONS, AND LIVELIHOODS ARE TO BE PROTECTED. *SOURCE: U.S. GEOLOGICAL SURVEY.*



18 KEY MESSAGE #3

MAINTAINING URBAN AREAS AND COMMUNITIES AND THEIR INTERCONNECTEDNESS

THE NORTHEAST'S URBAN CENTERS AND THEIR INTERCONNECTIONS ARE REGIONAL AND NATIONAL HUBS FOR CULTURAL AND ECONOMIC ACTIVITY. MAJOR NEGATIVE IMPACTS ON CRITICAL INFRASTRUCTURE, URBAN ECONOMIES, AND NATIONALLY SIGNIFICANT HISTORIC SITES ARE ALREADY OCCURRING AND WILL BECOME MORE COMMON WITH A CHANGING CLIMATE.

FIG 18.9: KING TIDE FLOODING IN ANNAPOLIS, MARYLAND

THE PHOTO SHOWS KING TIDE FLOODING ON DOCK STREET IN ANNAPOLIS, MARYLAND, ON DECEMBER 21, 2012. *PHOTO CREDIT: AMY MCGOVERN* (CC BY 2.0).

FIG 18.10: SUBWAY AIR VENT FLOOD PROTECTION

THE PHOTO SHOWS A SUBWAY AIR VENT WITH A MULTIUSE RAISED FLOOD PROTECTION GRATE THAT WAS INSTALLED AS PART OF THE POST–SUPERSTORM SANDY COASTAL RESILIENCE EFFORTS ON WEST BROADWAY IN LOWER MANHATTAN, NEW YORK CITY. *PHOTO CREDIT: WILLIAM SOLECKI.*

18 KEY MESSAGE #4

THREATS TO HUMAN HEALTH

CHANGING CLIMATE THREATENS THE HEALTH AND WELL-BEING OF PEOPLE IN THE NORTHEAST THROUGH MORE EXTREME WEATHER, WARMER TEMPERATURES, DEGRADATION OF AIR AND WATER QUALITY, AND SEA LEVEL RISE. THESE ENVIRONMENTAL CHANGES ARE EXPECTED TO LEAD TO HEALTH-RELATED IMPACTS AND COSTS, INCLUDING ADDITIONAL DEATHS, EMERGENCY ROOM VISITS AND HOSPITALIZATIONS, AND A LOWER QUALITY OF LIFE. HEALTH IMPACTS ARE EXPECTED TO VARY BY LOCATION, AGE, CURRENT HEALTH, AND OTHER CHARACTERISTICS OF INDIVIDUALS AND COMMUNITIES.

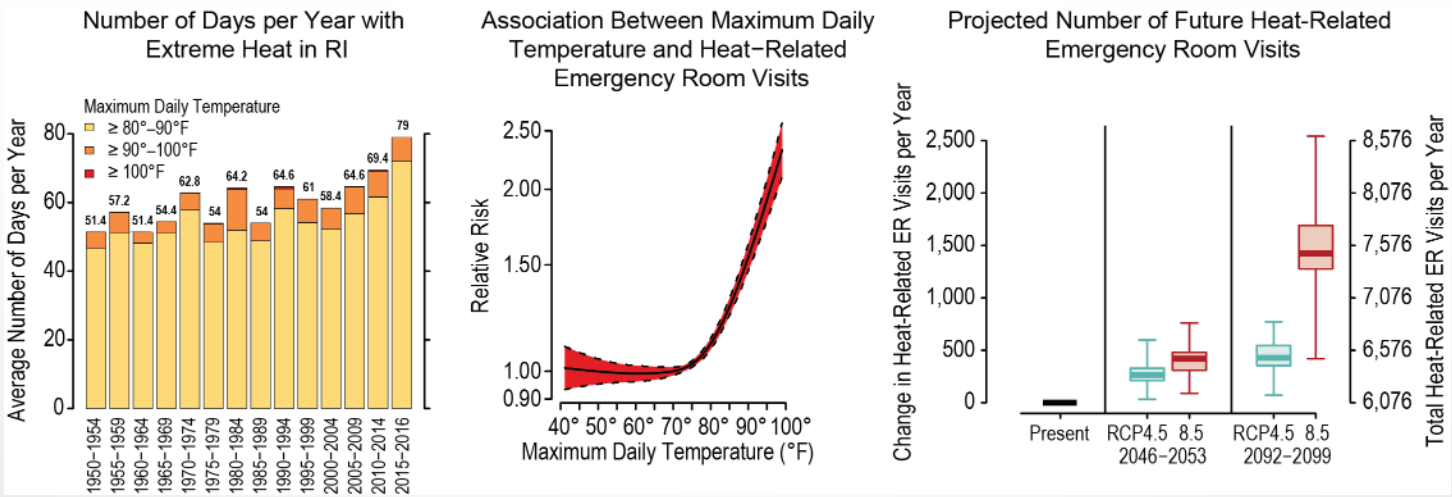


FIG. 18.11: OBSERVED AND PROJECTED IMPACTS OF EXCESS HEAT ON EMERGENCY ROOM VISITS IN RHODE ISLAND

THIS FIGURE SHOWS THE OBSERVED AND PROJECTED IMPACTS OF EXCESS HEAT ON EMERGENCY ROOM VISITS IN RHODE ISLAND. (LEFT) IN RHODE ISLAND, MAXIMUM DAILY TEMPERATURES IN THE SUMMER HAVE TRENDED UPWARDS OVER THE LAST 60 YEARS, SUCH THAT RESIDENTS EXPERIENCED ABOUT THREE MORE WEEKS OF HEALTH-THREATENING HOT WEATHER OVER 2015–2016 THAN IN THE 1950S. (MIDDLE) A RECENT STUDY LOOKING AT VISITS TO HOSPITAL EMERGENCY ROOMS (ERS) FOUND THAT THE INCIDENCE RATE OF HEAT-RELATED ER VISITS ROSE SHARPLY AS MAXIMUM DAILY TEMPERATURES CLIMBED ABOVE 80°F. (RIGHT) THE STUDY ESTIMATES THAT WITH CONTINUED CLIMATE CHANGE, RHODE ISLANDERS COULD EXPERIENCE AN ADDITIONAL 400 (6.8% MORE) HEAT-RELATED ER VISITS EACH YEAR BY 2050 AND UP TO AN ADDITIONAL 1,500 (24.4% MORE) SUCH VISITS EACH YEAR BY 2095 UNDER THE HIGHER SCENARIO (RCP8.5). ABOUT 1,000 FEWER ANNUAL HEAT-RELATED ER VISITS ARE PROJECTED FOR THE END OF THE CENTURY UNDER THE LOWER SCENARIO (RCP4.5) COMPARED TO THE HIGHER SCENARIO (RCP8.5), REFLECTING THE ESTIMATED HEALTH BENEFITS OF ADHERING TO A LOWER GREENHOUSE GAS EMISSIONS SCENARIO. *SOURCES: (LEFT) BROWN UNIVERSITY; (MIDDLE, RIGHT) ADAPTED FROM KINGSLEY ET AL. 2016.*[26] *REPRODUCED FROM ENVIRONMENTAL HEALTH PERSPECTIVES.*

18 KEY MESSAGE #5

ADAPTATION TO CLIMATE CHANGE IS UNDERWAY

COMMUNITIES IN THE NORTHEAST ARE PROACTIVELY PLANNING AND IMPLEMENTING ACTIONS TO REDUCE RISKS POSED BY CLIMATE CHANGE. USING DECISION SUPPORT TOOLS TO DEVELOP AND APPLY ADAPTATION STRATEGIES INFORMS BOTH THE VALUE OF ADOPTING SOLUTIONS AND THE REMAINING CHALLENGES. EXPERIENCE SINCE THE LAST ASSESSMENT PROVIDES A FOUNDATION TO ADVANCE FUTURE ADAPTATION EFFORTS.

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Read the full chapter

HTTPS://NCA2018.GLOBALCHANGE.GOV/CHAPTER/NORTHEAST

nca2018.globalchange.gov

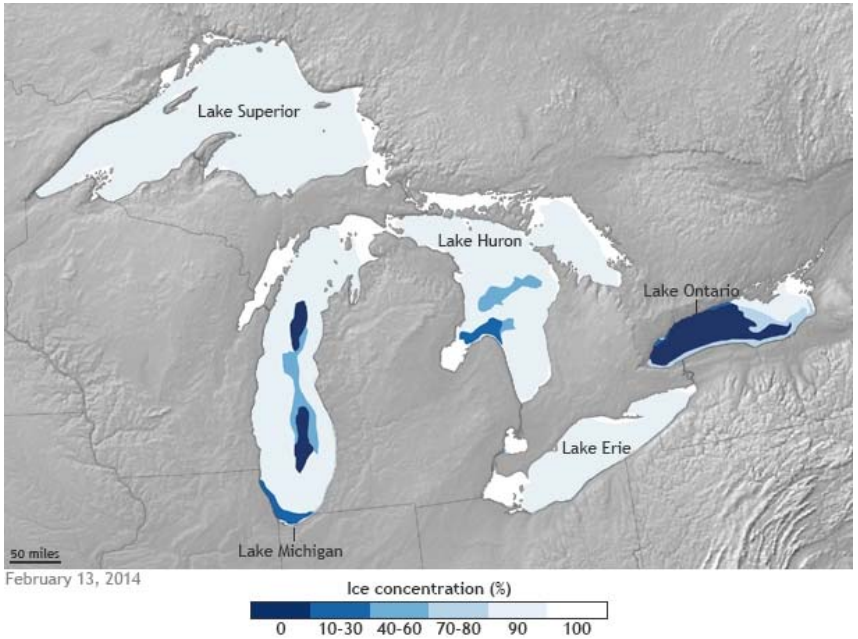
What does climate change look like in Vermont?

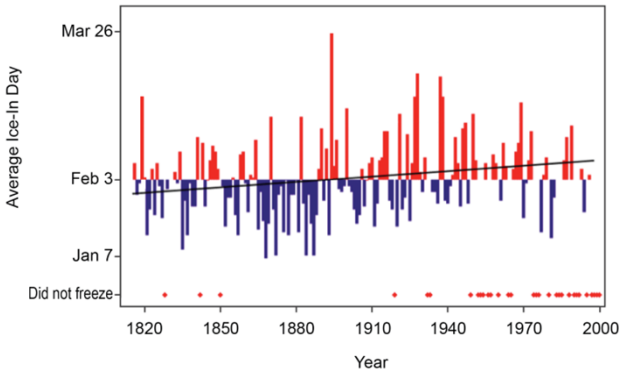
Lake Champlain – an integrator of climate

12 February 2014

88% frozen (2014)
82% frozen (1996)

National Climate Assessment, 2013





Date of ice-in on the main portion of Lake Champlain

NOAA & National Weather Service

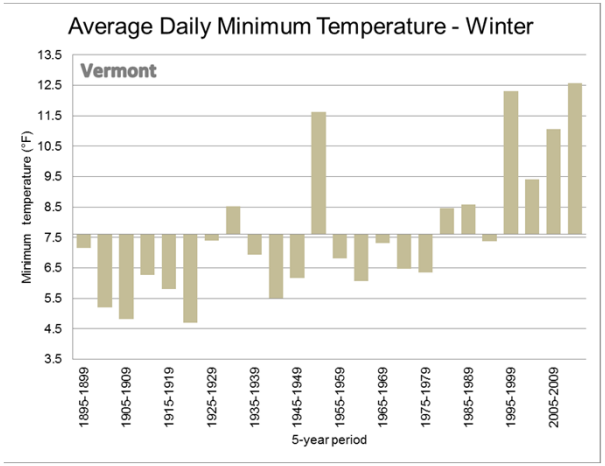
Backward spring

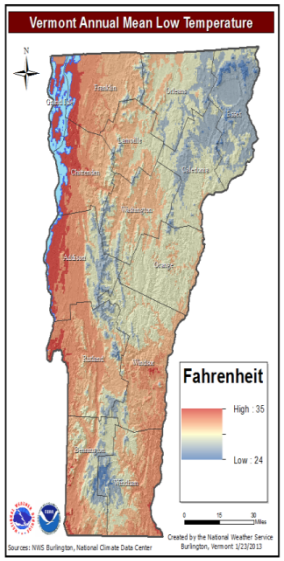
Photo credit: L-A. & M. Dupigny-Giroux

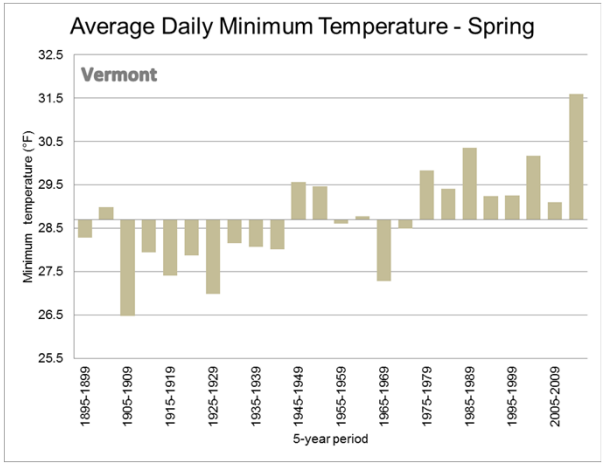
- low temperatures in January – June
- land-locked stations colder
- winter freeze/thaw cycles – predictor
- snow, freezing rain – April to June
- summer killing frosts
- summer drought
- NW flow

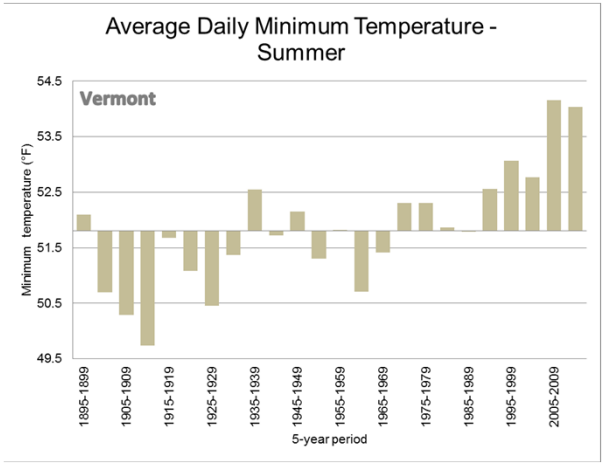
Dupigny-Giroux, L.-A. (2009) "Backward seasons, droughts and other bioclimatic indicators of variability," in Historical climate variability and impacts in North America, Lesley-Ann Dupigny-Giroux and Cary Mock (Editors), Springer Publishers, pp.231-250.

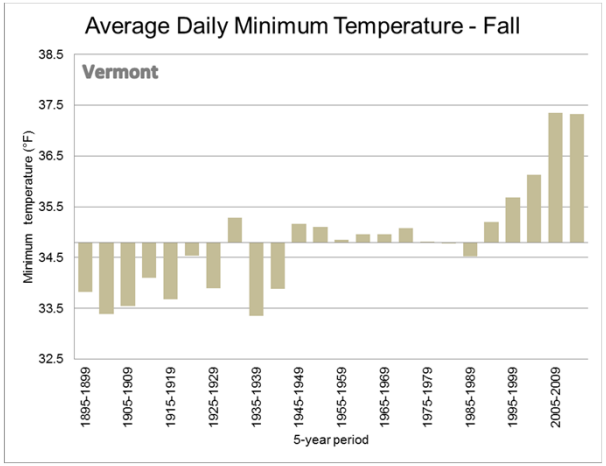
Daily low temperatures are getting warmer







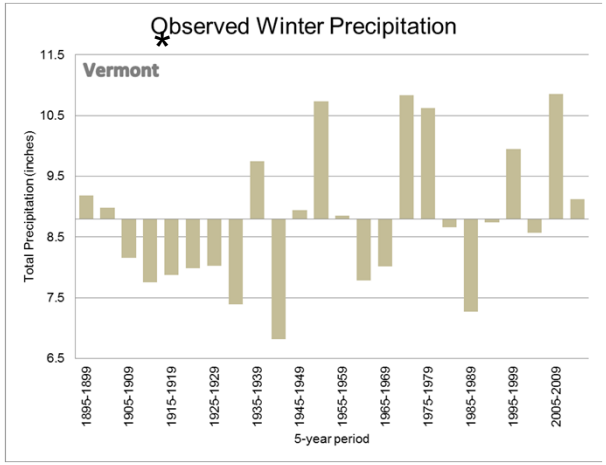


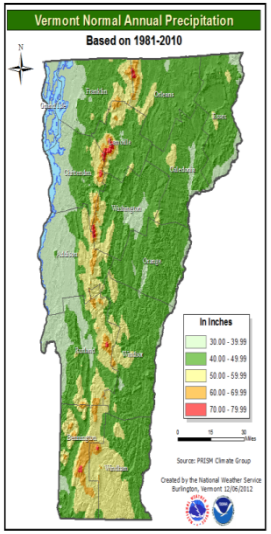


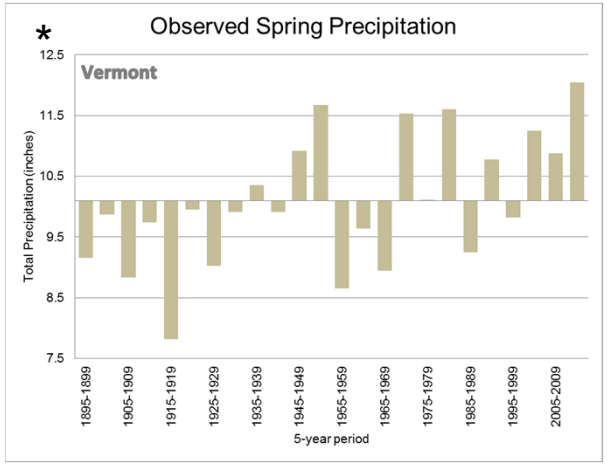
1895-2014, averaged over 5-year periods

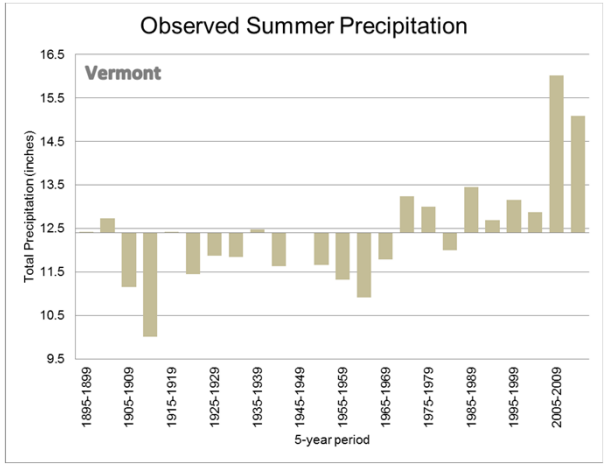
https://statesummaries.ncics.org/vt

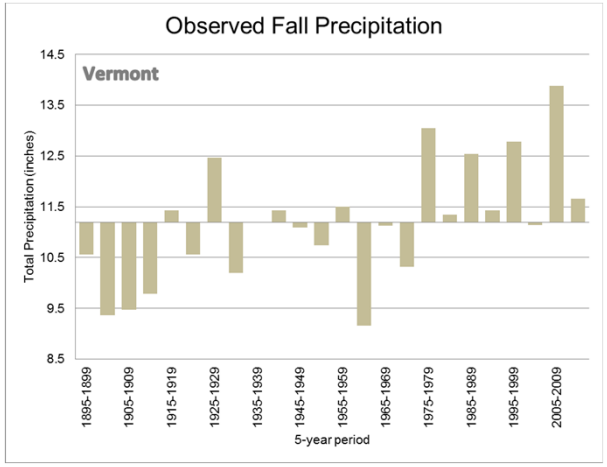
Variations in the amount of precipitation







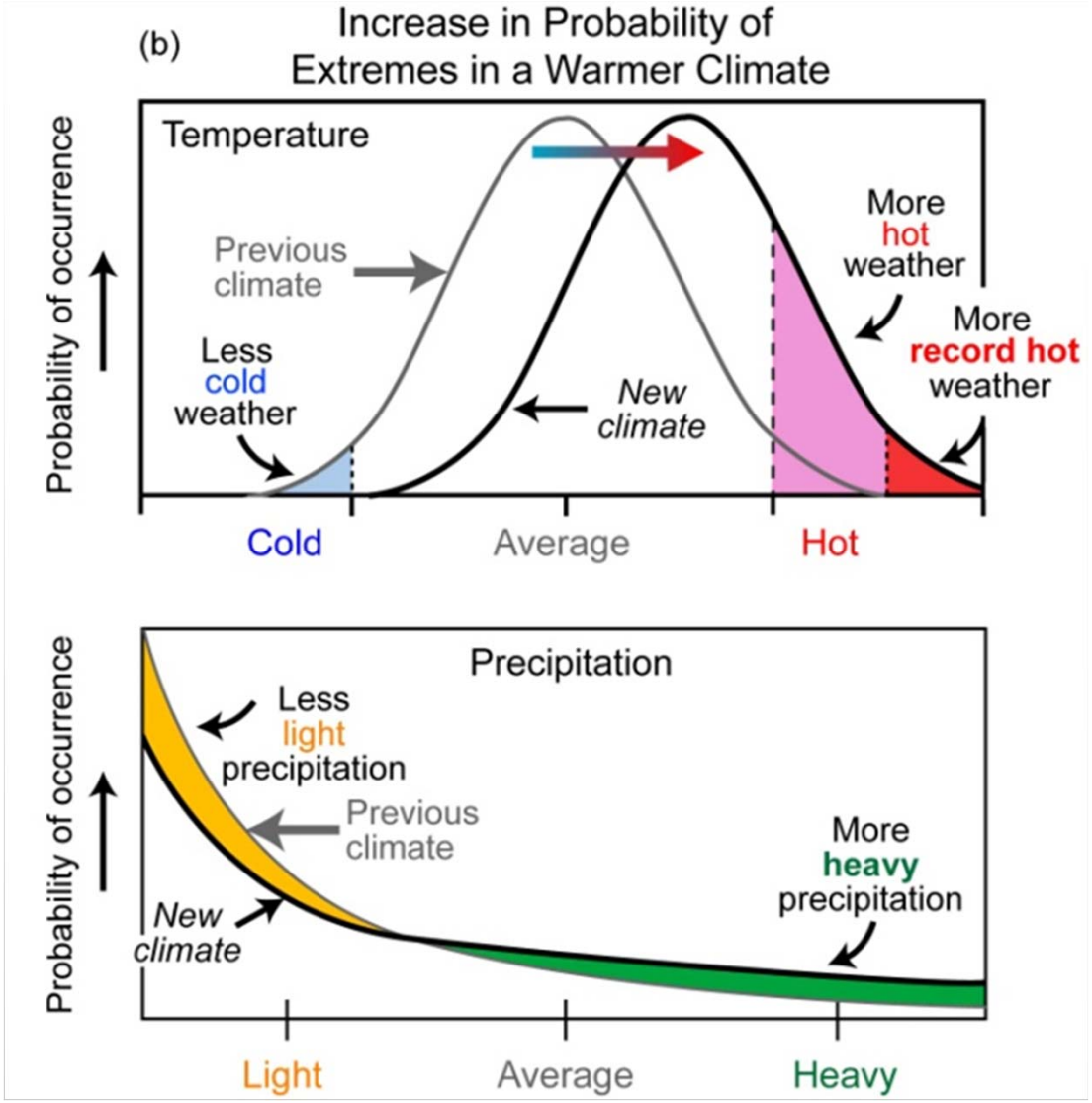




1895-2014, averaged over 5-year periods

https://statesummaries.ncics.org/vt

A warmer world increases the probability of extreme events



Courtesy: David Herring, NOAA

Sectors that are susceptible to a changing climate

Sectors that are susceptible to a changing climate

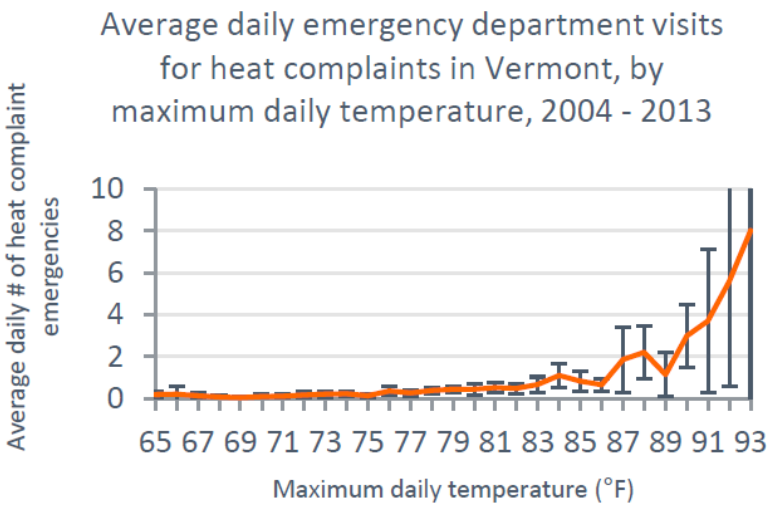
- infrastructure
- emergency management
- human health
- forestry
- agriculture
- tourism & recreation

Human health

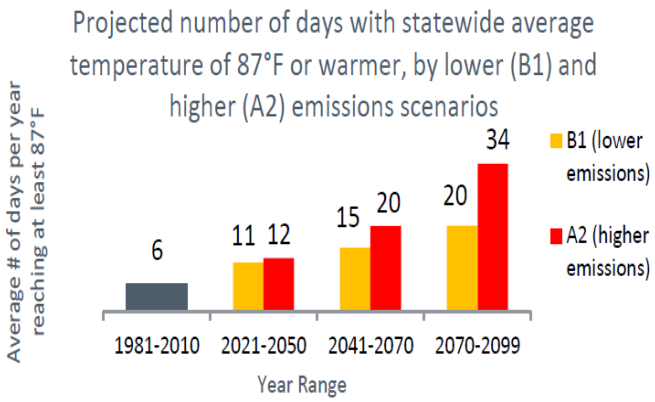
- hot weather (87°F)
- vulnerable populations
- rising low temperatures

- Lyme disease
- ground-level ozone

- climate refugees



Data sources: temperature data - PRISM Climate Group, in partnership with the Vermont State Climate Office; emergency department data - Early Aberration Reporting System (EARS).



Projection Source: Vermont State Climate Office

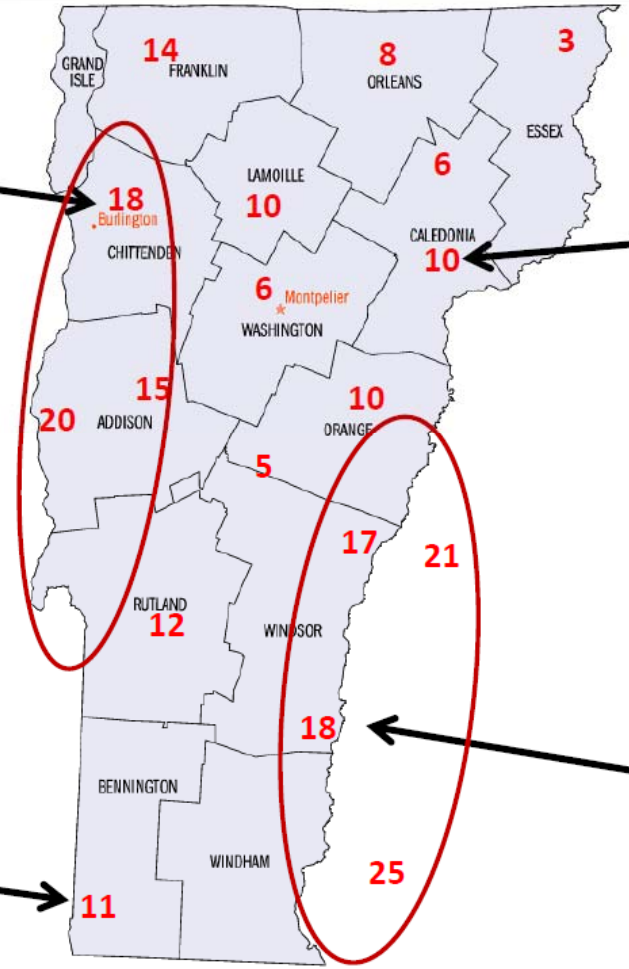
VERMONT
DEPARTMENT OF HEALTH

Climatology of Mean # Days ≥ 87°

2000-2016

Year	Number of Days Max Temperature >= 87
2000	4
2001	24
2002	26
2003	18
2004	5
2005	24
2006	11
2007	21
2008	7
2009	9
2010	24
2011	15
2012	24
2013	19
2014	12
2015	23
2016	32

Year	Number of Days Max Temperature >= 87
2000	1
2001	27
2002	25
2003	8
2004	3
2005	13
2006	9
2007	14
2008	5
2009	6
2010	12
2011	9
2012	9
2013	11
2014	3
2015	8
2016	10



Year	Number of Days Max Temperature >= 87
2000	3
2001	9
2002	18
2003	3
2004	3
2005	18
2006	8
2007	13
2008	4
2009	6
2010	16
2011	9
2012	16
2013	16
2014	6
2015	16
2016	16

Year	Number of Days Max Temperature >= 87
2000	6
2001	26
2002	33
2003	13
2004	6
2005	27
2006	13
2007	17
2008	9
2009	8
2010	30
2011	18
2012	32
2013	16
2014	5
2015	22
2016	20

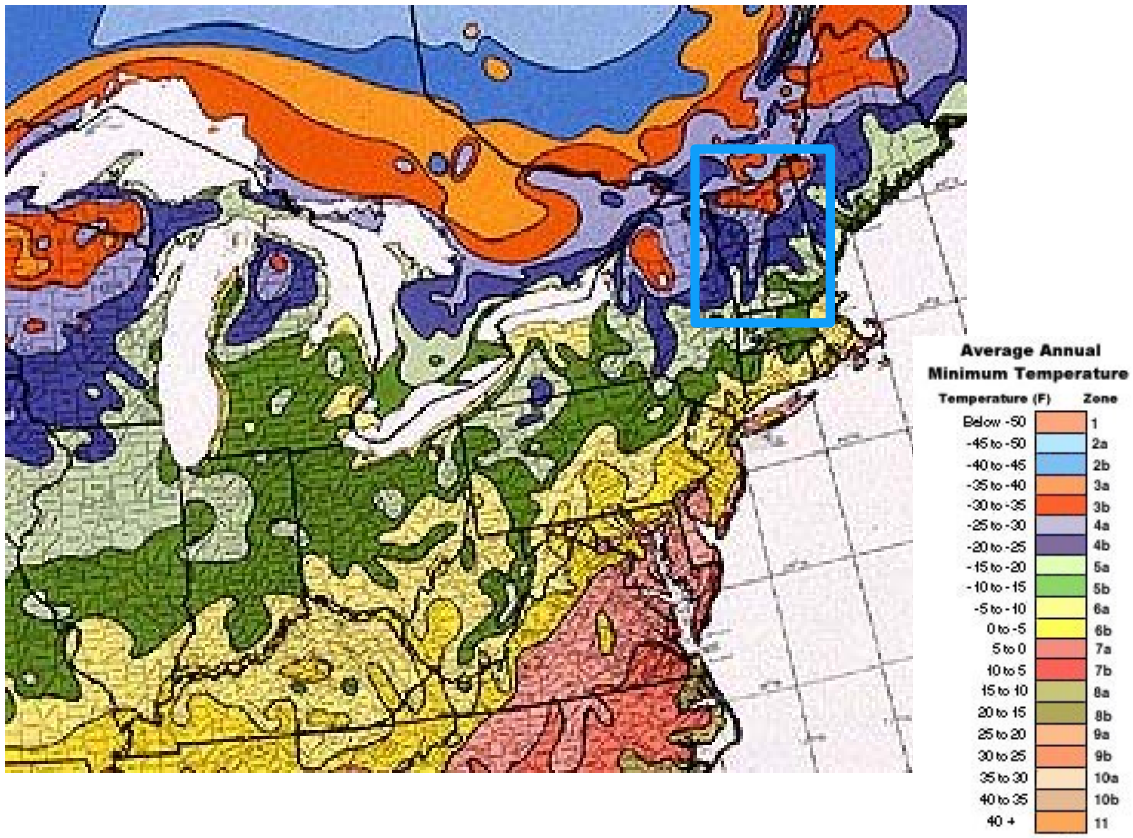
National Weather Service **Burlington** Follow Us: *www.weather.gov/btv*

Courtesy: NWS/Scott Whittier

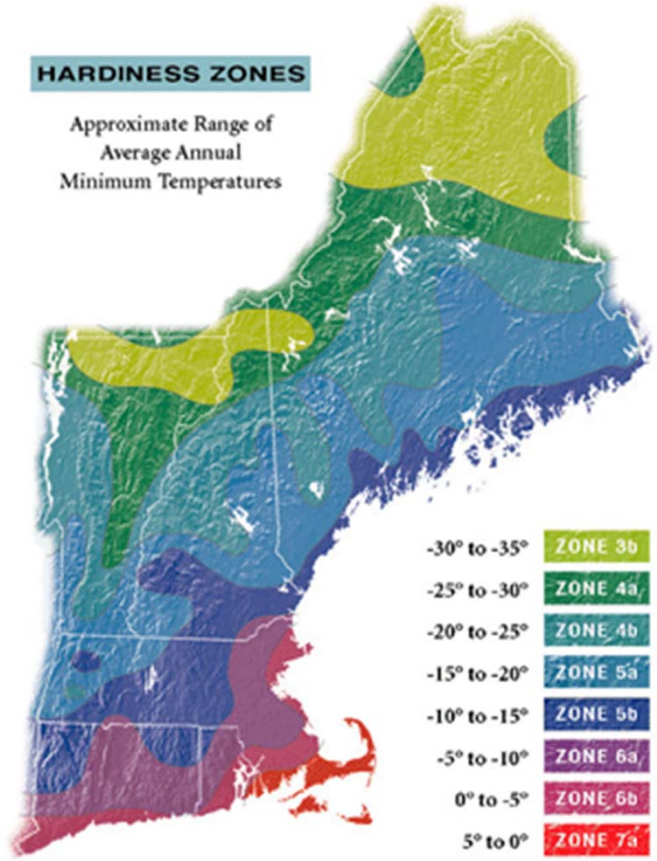
Vegetation

http://usna.usda.gov/Hardzone/hzm-ne1.html
http://www.arborday.org/treeinfo/zonelookup.cfm

Plant hardiness maps

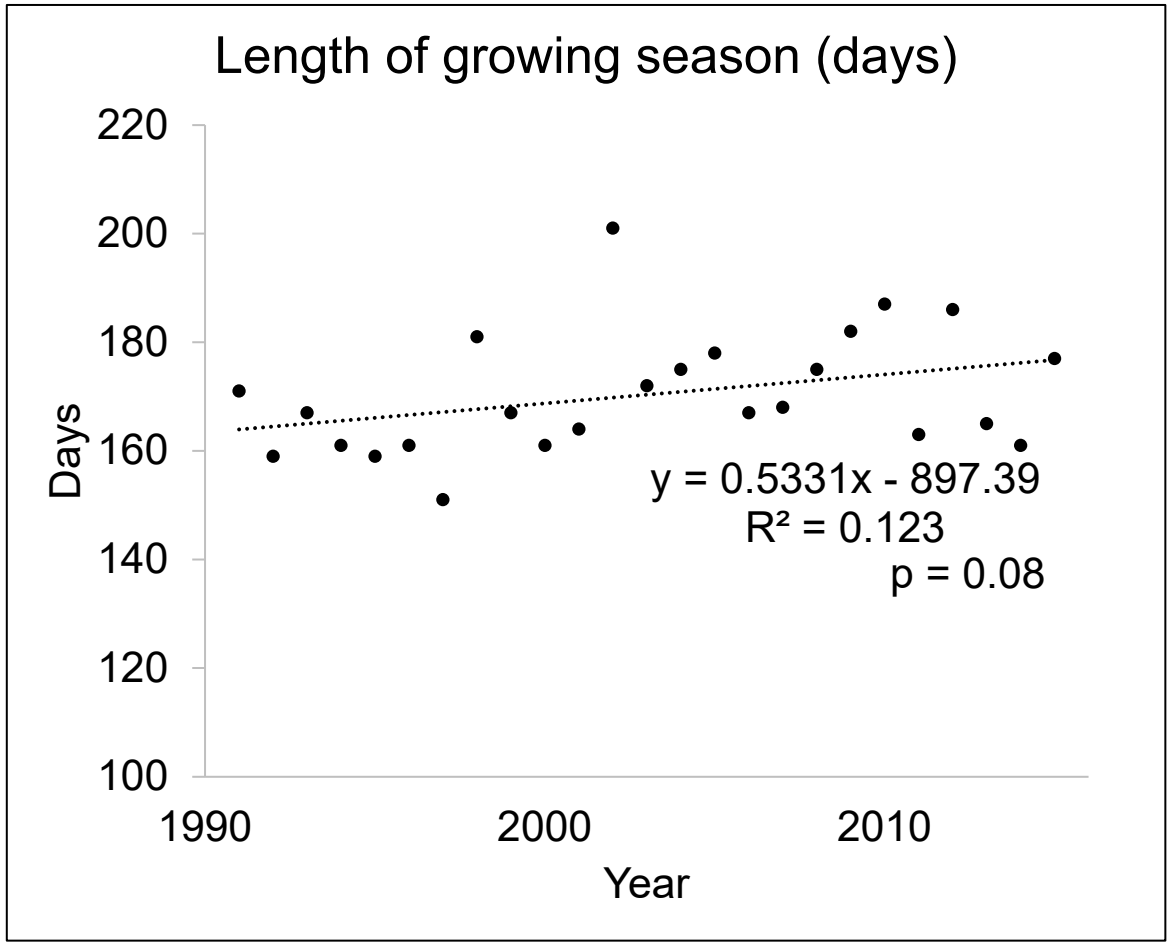


USDA National Arboretum



Arbor Day Foundation

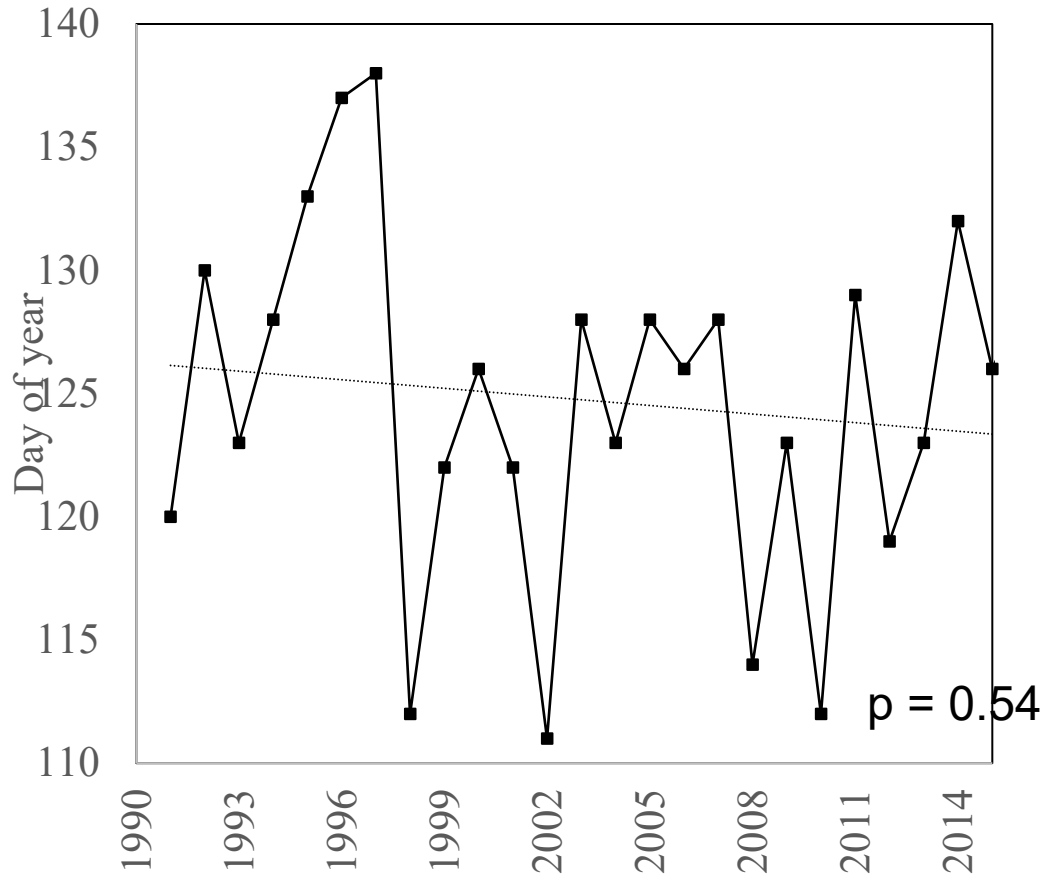
Length of growing season – gradually extending (Underhill site)



Josh Halman
VT Dept. of Forests, Parks and Recreation

Early Season Phenology: 1990 - 2016

Average Sugar Maple Budbreak – Underhill site



Josh Halman
VT Dept. of Forests, Parks and Recreation

Ground-level ozone

Ozone Injury to White Ash
Photo by Gretchen Smith

- reduces plant growth & vigor
- reduces seed production
- increases susceptibility to insects & disease
- cumulative effect over growing season
- Black cherry, white ash, yellow poplar

Recreation and tourism

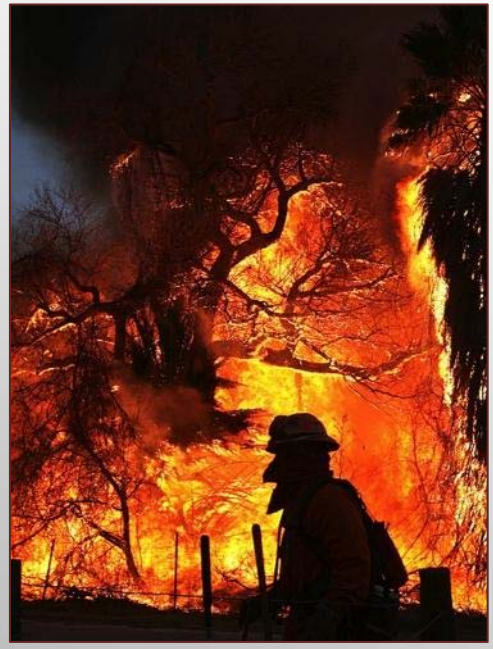
- lake and river-based activities
  - water temperatures
  - water levels
- cold-season activities
  - snowfall
  - drought
- leaf peeping

Photos: L-A. Dupigny-Giroux

Infrastructure

- roads and highways
- rail (heat) and airports (blizzards)
- electrical grid
- water supplies
- critical infrastructure

PEOPLE & COMMUNITIES ARE EXPERIENCING MORE / MORE FREQUENT EXTREME EVENTS…



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Courtesy: David Herring, NOAA

…WITH COSTLY DAMAGES TO PROPERTY, STRUCTURES, AND INFRASTRUCTURE.

Credit: Vermont Pilot, Steve Earley

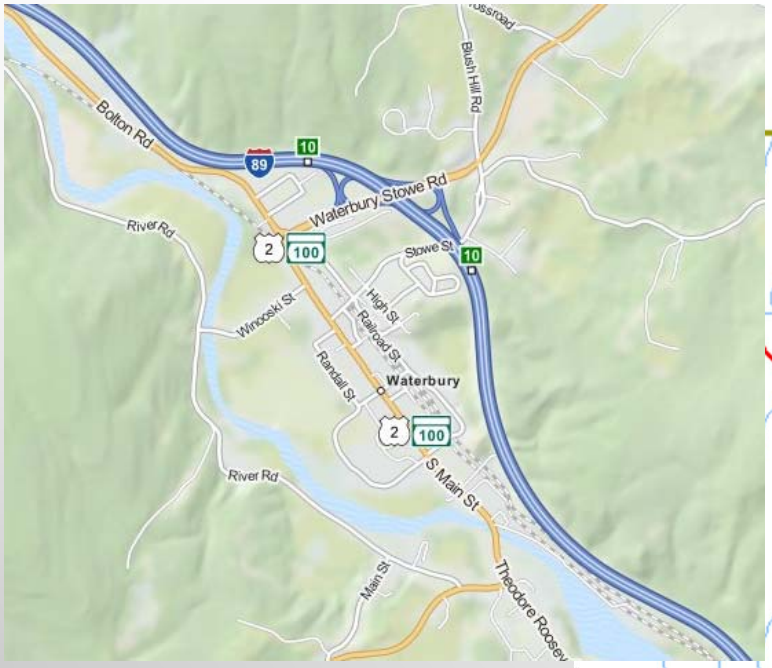
Source: U.S. Postal Service, 2014

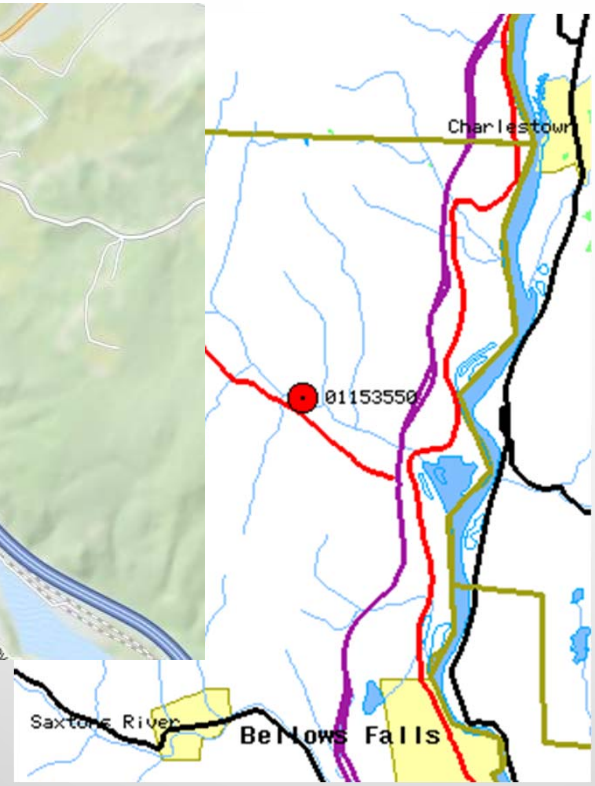
Credit: William Vantuono, Railway Age Magazine, 2012

Credit: Vermont Agency of Transportation, 2013

Courtesy: David Herring, NOAA

JUXTAPOSITION OF RIVERS & ROADS TAKES A TOLL ON INFRASTRUCTURE

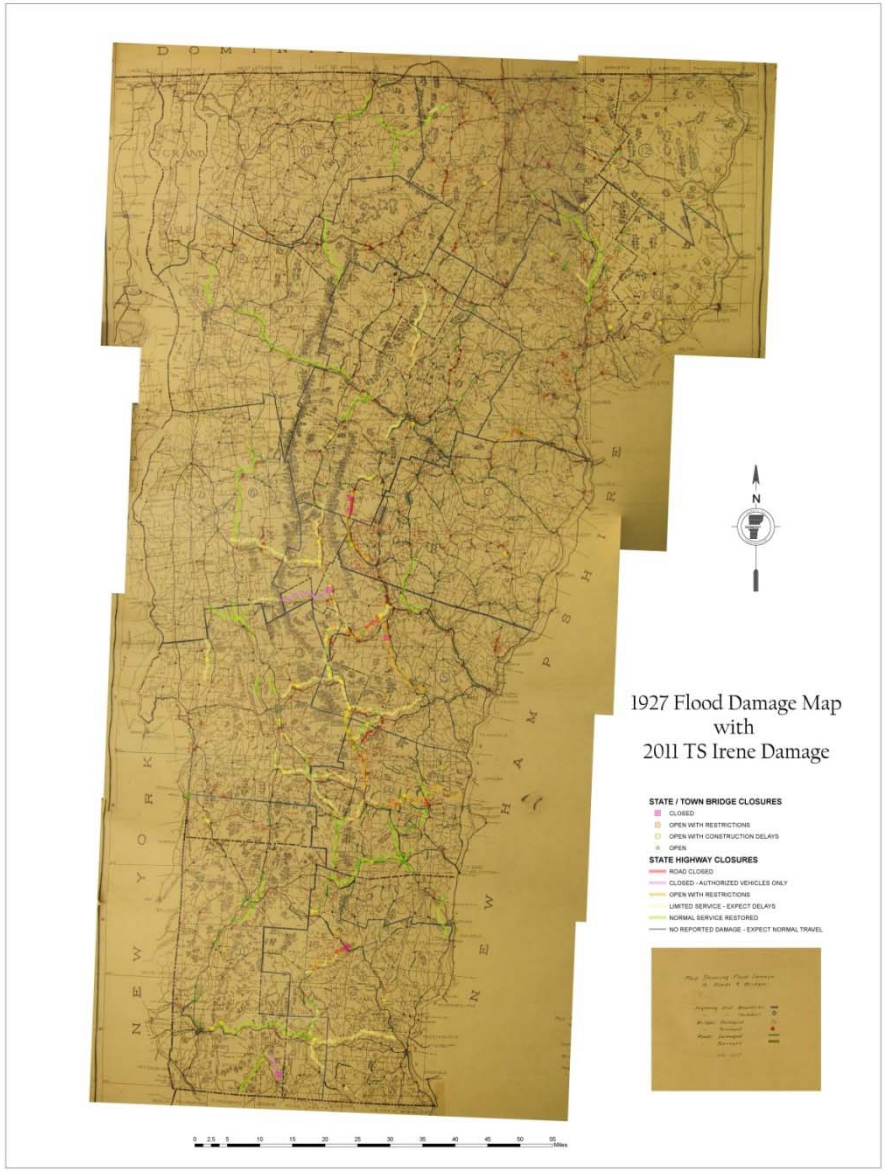




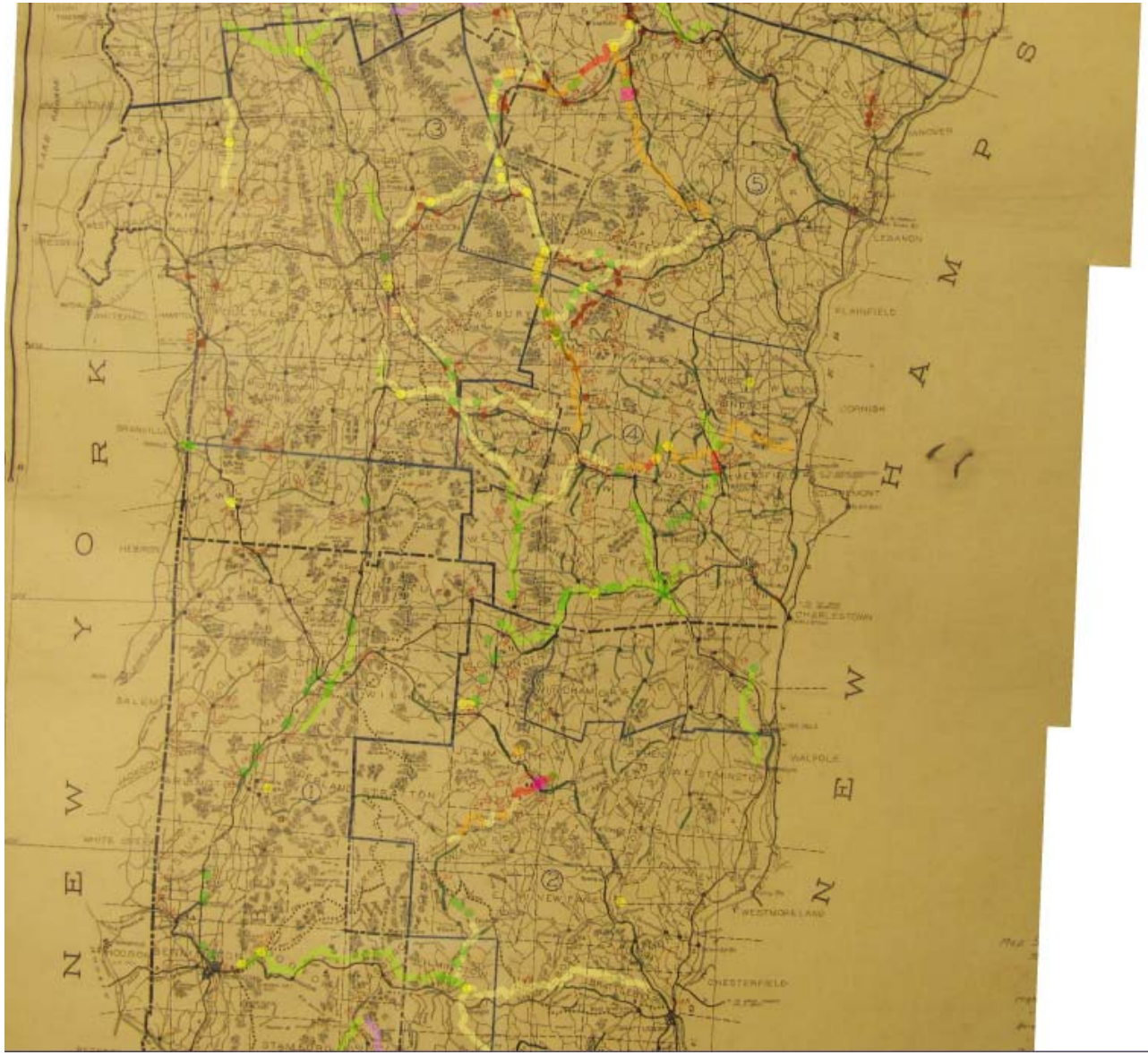
- REPEAT OCCURRENCES IN PREFERRED LOCATIONS
  - JAY PEAK, ROUTE 100

Montgomery flooding - July 1997

Photo credit: NWS/BTV



Courtesy: Johnathan Croft, VTRans



1927 Flood Damage Map with 2011 TS Irene Damage

STATE / TOWN BRIDGE CLOSURES

- CLOSED
- OPEN WITH RESTRICTIONS
- OPEN WITH CONSTRUCTION DELAYS
- OPEN

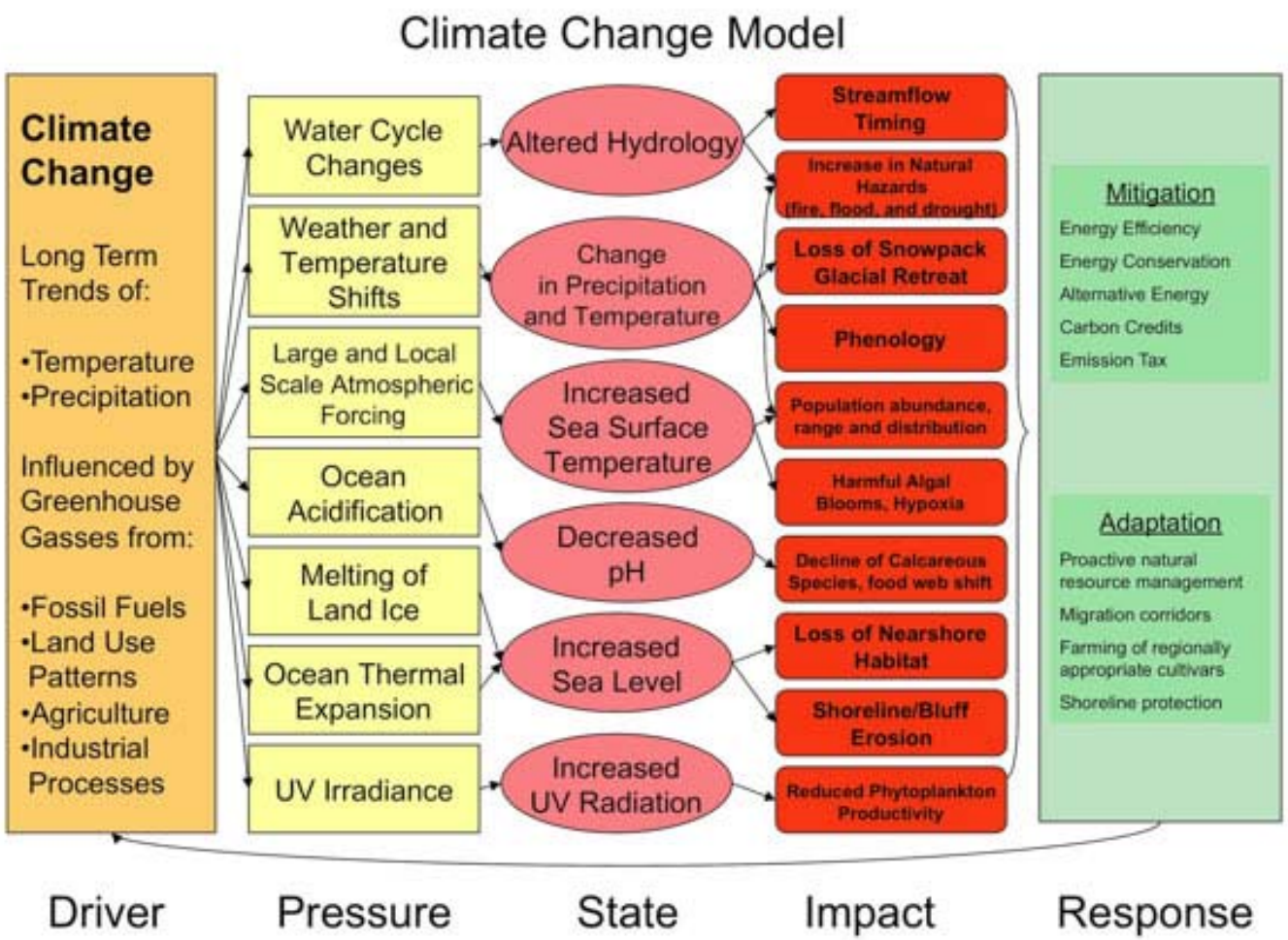
STATE HIGHWAY CLOSURES

- ROAD CLOSED
- CLOSED - AUTHORIZED VEHICLES ONLY
- OPEN WITH RESTRICTIONS
- LIMITED SERVICE - EXPECT DELAYS
- NORMAL SERVICE RESTORED
- NO REPORTED DAMAGE - EXPECT NORMAL TRAVEL

Courtesy: Johnathan Croft, VTRans

Strategies

Process, impact, strategies



http://pugetsoundscienceupdate.com/pmwiki.php?n=Chapter3.Section2

4. Actions to Reduce Risks

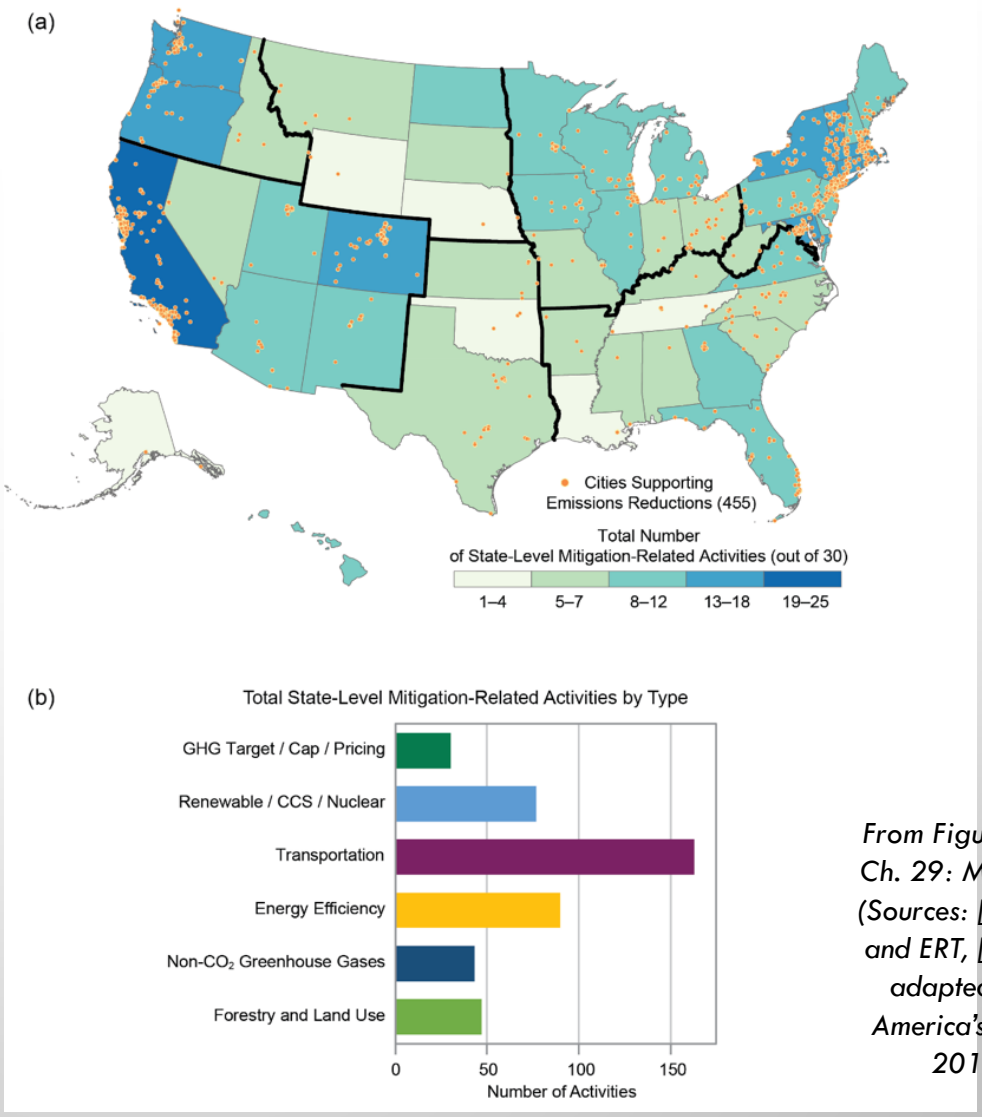
> *Communities, governments, and businesses are working to reduce risks from and costs associated with climate change by taking action to lower greenhouse gas emissions and implement adaptation strategies. While mitigation and adaptation efforts have expanded substantially in the last four years, they do not yet approach the scale considered necessary to avoid substantial damages to the economy, environment, and human health over the coming decades.*

Future risks from climate change depend primarily on decisions made today. The integration of climate risk into decision-making and the implementation of adaptation activities have significantly increased since the Third National Climate Assessment in 2014, including in areas of financial risk reporting, capital investment planning, development of engineering standards, military planning, and disaster risk management. Transformations in the energy sector—including the displacement of coal by natural gas and increased deployment of renewable energy—along with policy actions at the national, regional, state, and local levels are reducing greenhouse gas emissions in the United States. While these adaptation and mitigation measures can help reduce damages in a number of sectors, this assessment shows that more immediate and substantial global greenhouse gas emissions reductions, as well as regional adaptation efforts, would be needed to avoid the most severe consequences in the long term. Mitigation and adaptation actions also present opportunities for additional benefits that are often more immediate and localized, such as improving local air quality and economies through investments in infrastructure. Some benefits, such as restoring ecosystems and increasing community vitality, may be harder to quantify.

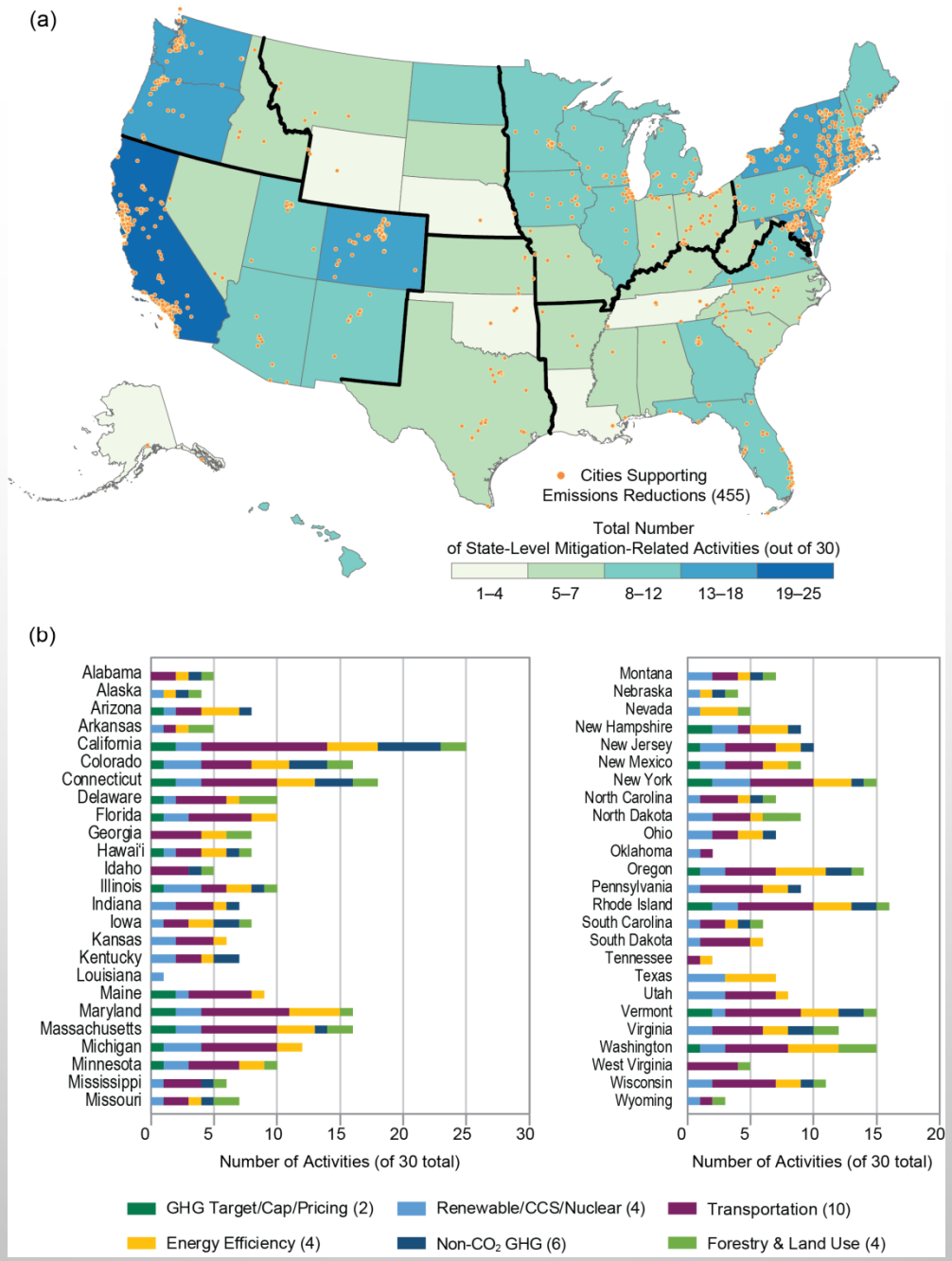
MITIGATION-RELATED ACTIVITIES AT STATE AND LOCAL LEVELS

(TOP) THE MAP SHOWS THE NUMBER OF MITIGATION-RELATED ACTIVITIES AT THE STATE LEVEL (OUT OF 30 ILLUSTRATIVE ACTIVITIES) AS WELL AS CITIES SUPPORTING EMISSIONS REDUCTIONS

(BOTTOM) THE CHART DEPICTS THE TYPE AND NUMBER OF ACTIVITIES BY STATE. SEVERAL TERRITORIES ALSO HAVE A VARIETY OF MITIGATION-RELATED ACTIVITIES, INCLUDING AMERICAN SĀMOA, THE FEDERATED STATES OF MICRONESIA, GUAM, NORTHERN MARIANA ISLANDS, PUERTO RICO, AND THE U.S. VIRGIN ISLANDS.



From Figure 29.1, Ch. 29: Mitigation (Sources: [top] EPA and ERT, [bottom] adapted from America's Pledge 2017).


(a)
Cities Supporting
Emissions Reductions (455)
Total Number
of State-Level Mitigation-Related Activities (out of 30)
1–4
5–7
8–12
13–18
19–25
(b)
Alabama
Alaska
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
Florida
Georgia
Hawai'i
Idaho
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
0
5
10
15
20
25
30
Number of Activities (of 30 total)
Montana
Nebraska
Nevada
New Hampshire
New Jersey
New Mexico
New York
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Rhode Island
South Carolina
South Dakota
Tennessee
Texas
Utah
Vermont
Virginia
Washington
West Virginia
Wisconsin
Wyoming
0
5
10
15
20
Number of Activities (of 30 total)
GHG Target/Cap/Pricing (2)
Renewable/CCS/Nuclear (4)
Transportation (10)
Energy Efficiency (4)
Non-CO2 GHG (6)
Forestry & Land Use (4)

10. Infrastructure

> *Our Nation's aging and deteriorating infrastructure is further stressed by increases in heavy precipitation events, coastal flooding, heat, wildfires, and other extreme events, as well as changes to average precipitation and temperature. Without adaptation, climate change will continue to degrade infrastructure performance over the rest of the century, with the potential for cascading impacts that threaten our economy, national security, essential services, and health and well-being.*

Climate change and extreme weather events are expected to increasingly disrupt our Nation's energy and transportation systems, threatening more frequent and longer-lasting power outages, fuel shortages, and service disruptions, with cascading impacts on other critical sectors. Infrastructure currently designed for historical climate conditions is more vulnerable to future weather extremes and climate change. The continued increase in the frequency and extent of high-tide flooding due to sea level rise threatens America's trillion-dollar coastal property market and public infrastructure, with cascading impacts to the larger economy. In Alaska, rising temperatures and erosion are causing damage to buildings and coastal infrastructure that will be costly to repair or replace, particularly in rural areas; these impacts are expected to grow without adaptation. Expected increases in the severity and frequency of heavy precipitation events will affect inland infrastructure in every region, including access to roads, the viability of bridges, and the safety of pipelines. Flooding from heavy rainfall, storm surge, and rising high tides is expected to compound existing issues with aging infrastructure in the Northeast. Increased drought risk will threaten oil and gas drilling and refining, as well as electricity generation from power plants that rely on surface water for cooling. Forward-looking infrastructure design, planning, and operational measures and standards can reduce exposure and vulnerability to the impacts of climate change and reduce energy use while providing additional near-term benefits, including reductions in greenhouse gas emissions.

FIVE ADAPTATION STAGES AND PROGRESS

ADAPTATION ENTAILS A CONTINUING RISK MANAGEMENT PROCESS. WITH THIS APPROACH, INDIVIDUALS AND ORGANIZATIONS BECOME AWARE OF AND ASSESS RISKS AND VULNERABILITIES FROM CLIMATE AND OTHER DRIVERS OF CHANGE, TAKE ACTIONS TO REDUCE THOSE RISKS, AND LEARN OVER TIME. THE GRAY ARCED LINES COMPARE THE CURRENT STATUS OF IMPLEMENTING THIS PROCESS WITH THE STATUS REPORTED BY THE THIRD NATIONAL CLIMATE ASSESSMENT IN 2014; DARKER COLOR INDICATES MORE ACTIVITY.

From Figure 28.1, Ch. 28: Adaptation (Source: adapted from National Research Council, 2010. Used with permission from the National Academies Press, © 2010,National Academy of Sciences. Image credits, clockwise from top: National Weather Service; USGS; Armando Rodriguez, Miami-Dade County; Dr. Neil Berg, MARISA; Bill Ingalls, NASA).

28 Key Message #4

Benefits of Proactive Adaptation Exceed Costs

Proactive adaptation initiatives—including changes to policies, business operations, capital investments, and other steps—yield benefits in excess of their costs in the near term, as well as over the long term. Evaluating adaptation strategies involves consideration of equity, justice, cultural heritage, the environment, health, and national security.

6. Health

> *Impacts from climate change on extreme weather and climate-related events, air quality, and the transmission of disease through insects and pests, food, and water increasingly threaten the health and well-being of the American people, particularly populations that are already vulnerable.*

Changes in temperature and precipitation are increasing air quality and health risks from wildfire and ground-level ozone pollution. Rising air and water temperatures and more intense extreme events are expected to increase exposure to waterborne and foodborne diseases, affecting food and water safety. With continued warming, cold-related deaths are projected to decrease and heat-related deaths are projected to increase; in most regions, increases in heat-related deaths are expected to outpace reductions in cold-related deaths. The frequency and severity of allergic illnesses, including asthma and hay fever, are expected to increase as a result of a changing climate. Climate change is also projected to alter the geographic range and distribution of disease-carrying insects and pests, exposing more people to ticks that carry Lyme disease and mosquitoes that transmit viruses such as Zika, West Nile, and dengue, with varying impacts across regions. Communities in the Southeast, for example, are particularly vulnerable to the combined health impacts from vector-borne disease, heat, and flooding. Extreme weather and climate-related events can have lasting mental health consequences in affected communities, particularly if they result in degradation of livelihoods or community relocation. Populations including older adults, children, low-income communities, and some communities of color are often disproportionately affected by, and less resilient to, the health impacts of climate change. Adaptation and mitigation policies and programs that help individuals, communities, and states prepare for the risks of a changing climate reduce the number of injuries, illnesses, and deaths from climate-related health outcomes.

https://nca2018.globalchange.gov/

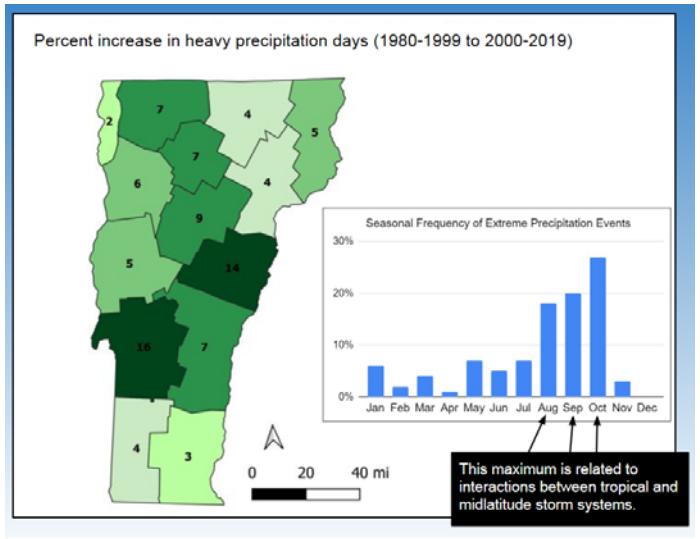
7. Indigenous Peoples

> *Climate change increasingly threatens Indigenous communities' livelihoods, economies, health, and cultural identities by disrupting interconnected social, physical, and ecological systems.*

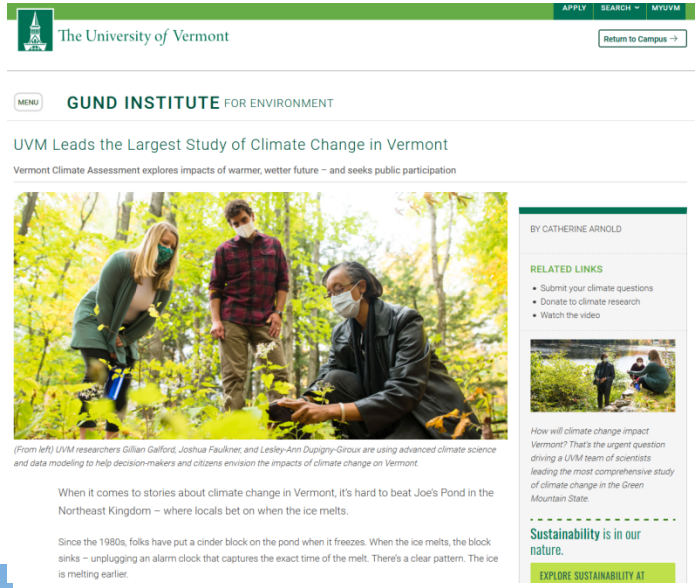
Many Indigenous peoples are reliant on natural resources for their economic, cultural, and physical well-being and are often uniquely affected by climate change. The impacts of climate change on water, land, coastal areas, and other natural resources, as well as infrastructure and related services, are expected to increasingly disrupt Indigenous peoples' livelihoods and economies, including agriculture and agroforestry, fishing, recreation, and tourism. Adverse impacts on subsistence activities have already been observed. As climate changes continue, adverse impacts on culturally significant species and resources are expected to result in negative physical and mental health effects. Throughout the United States, climate-related impacts are causing some Indigenous peoples to consider or actively pursue community relocation as an adaptation strategy, presenting challenges associated with maintaining cultural and community continuity. While economic, political, and infrastructure limitations may affect these communities' ability to adapt, tightly knit social and cultural networks present opportunities to build community capacity and increase resilience. Many Indigenous peoples are taking steps to adapt to climate change impacts structured around self-determination and traditional knowledge, and some tribes are pursuing mitigation actions through development of renewable energy on tribal lands.

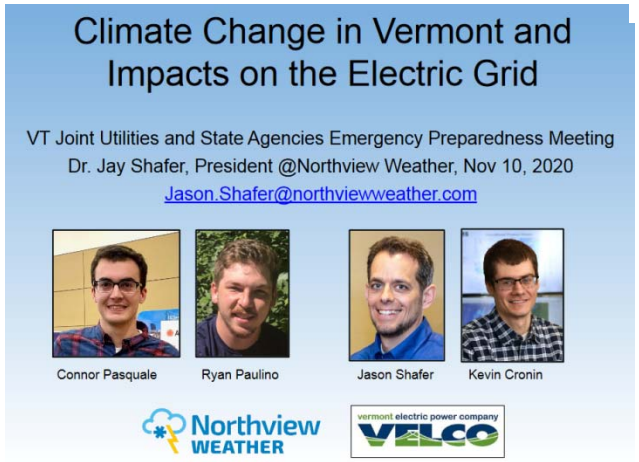
https://nca2018.globalchange.gov/

Additional resources



https://www.uvm.edu/gund/news/uvm-leads-largest-study-climate-change-vermont





https://statesummaries.ncics.org/chapter/vt/

https://climatecouncil.maine.gov/

Closing thoughts

- geographies of vulnerability (digital, homeless, access to healthcare)

- human-environment dimensions

- multi-scalar approach
- systems science
- interdisciplinarity and core disciplines

- flexible, nimble and quick

Thank you!

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