

Maine's possible future given the global climate crisis

A Presentation to the Maine Coast Forum

Paul Andrew Mayewski



Climate Change Institute |



University of Maine



**Global Impact
Local Relevance**

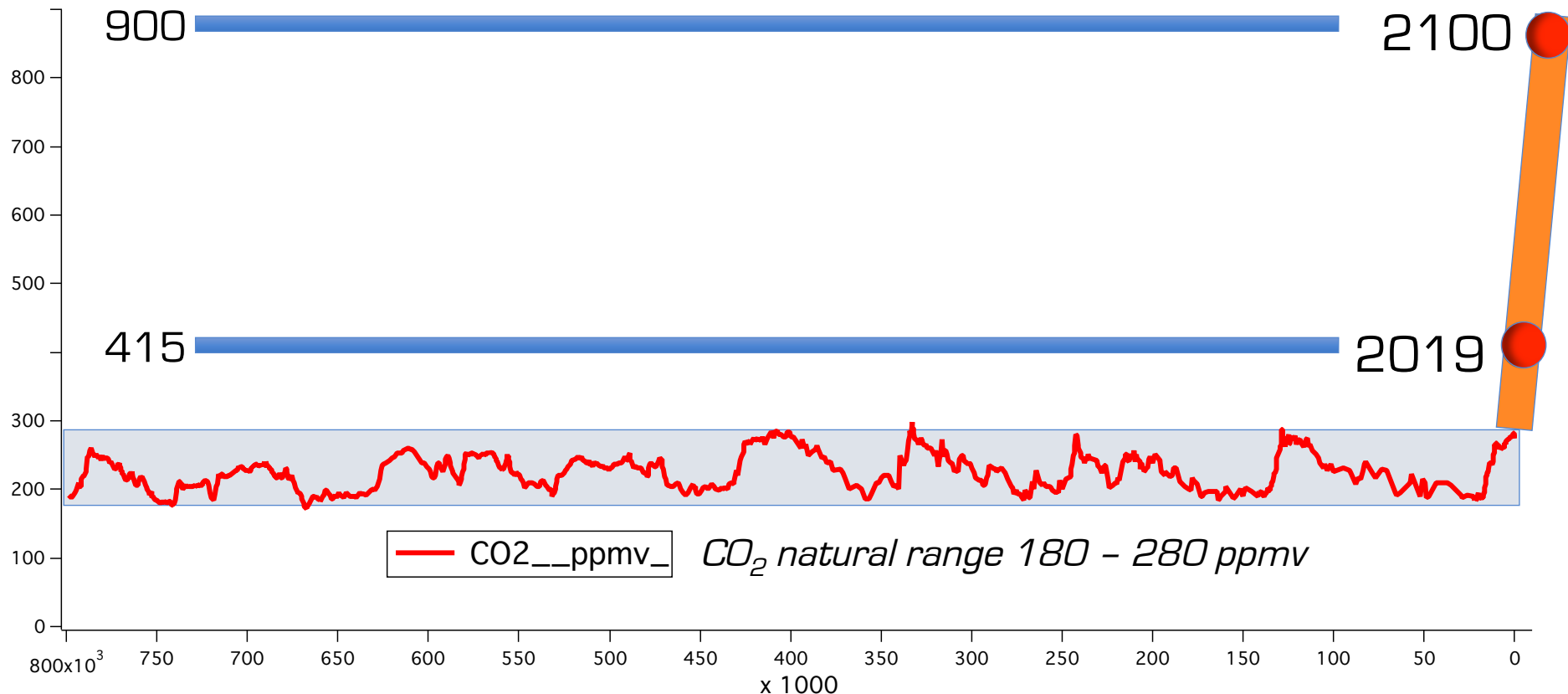
Maine's Research University at Work

umaine.edu/research

*We shall not cease from exploration, and
the end of all our exploring will be to arrive
where we started and know the place for
the first time.* T. S. Eliot



*CO₂ today 1.5 times higher
and 100 times faster rise*

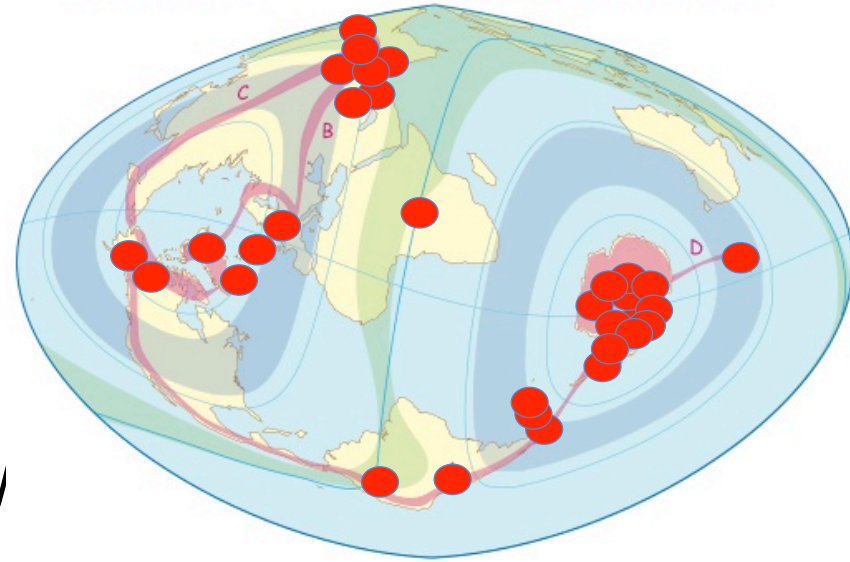
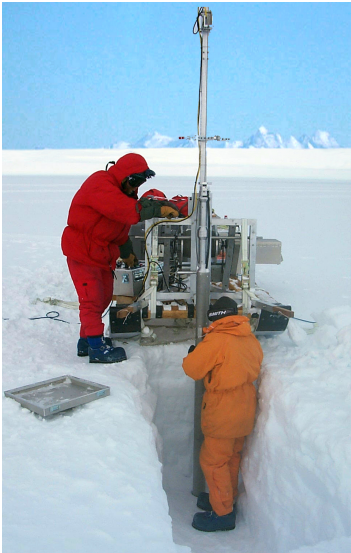


850,000 years

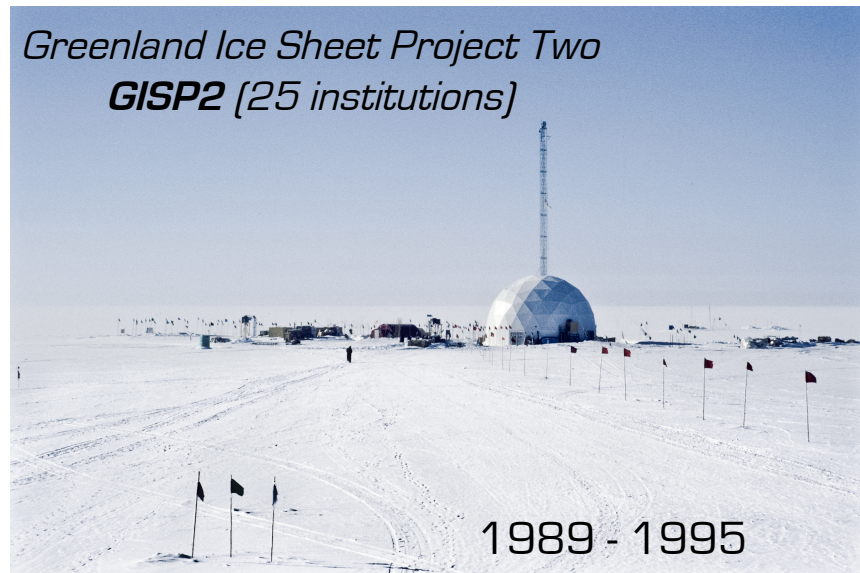
Ice cores provide perspective

Storm by storm, season by season back
decades to millennia for:

temperature
precipitation
atmospheric
circulation
sea ice extent
biological productivity
volcanic activity
atmospheric chemistry
(gases, dissolved ions,
trace chemistry)

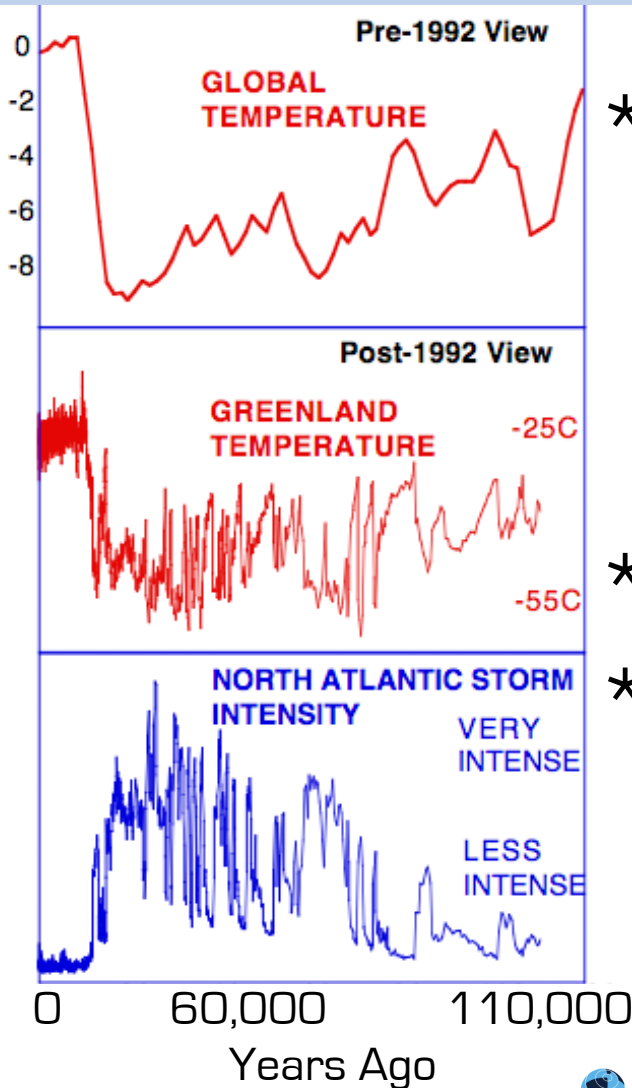


The first continuous and the most detailed climate record for the past 110,000 years



A dramatic shift in thinking!

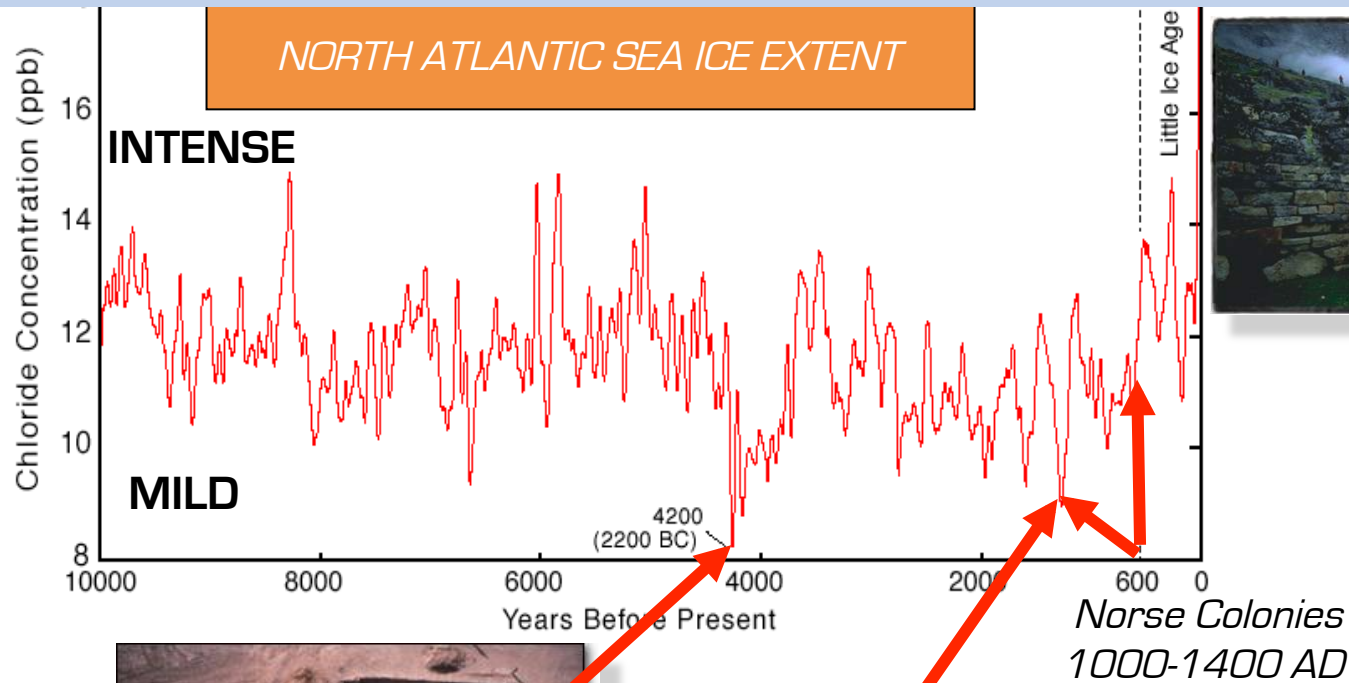
Climate CAN change VERY abruptly



- * Massive shifts in:
 - storm frequency/intensity
 - precipitation
 - temperature
- * In less than 1-5 years
- * Sustained for decades and more



Abrupt climate change and the collapse of civilization



*4200 years ago
Mesopotamian
Collapse*

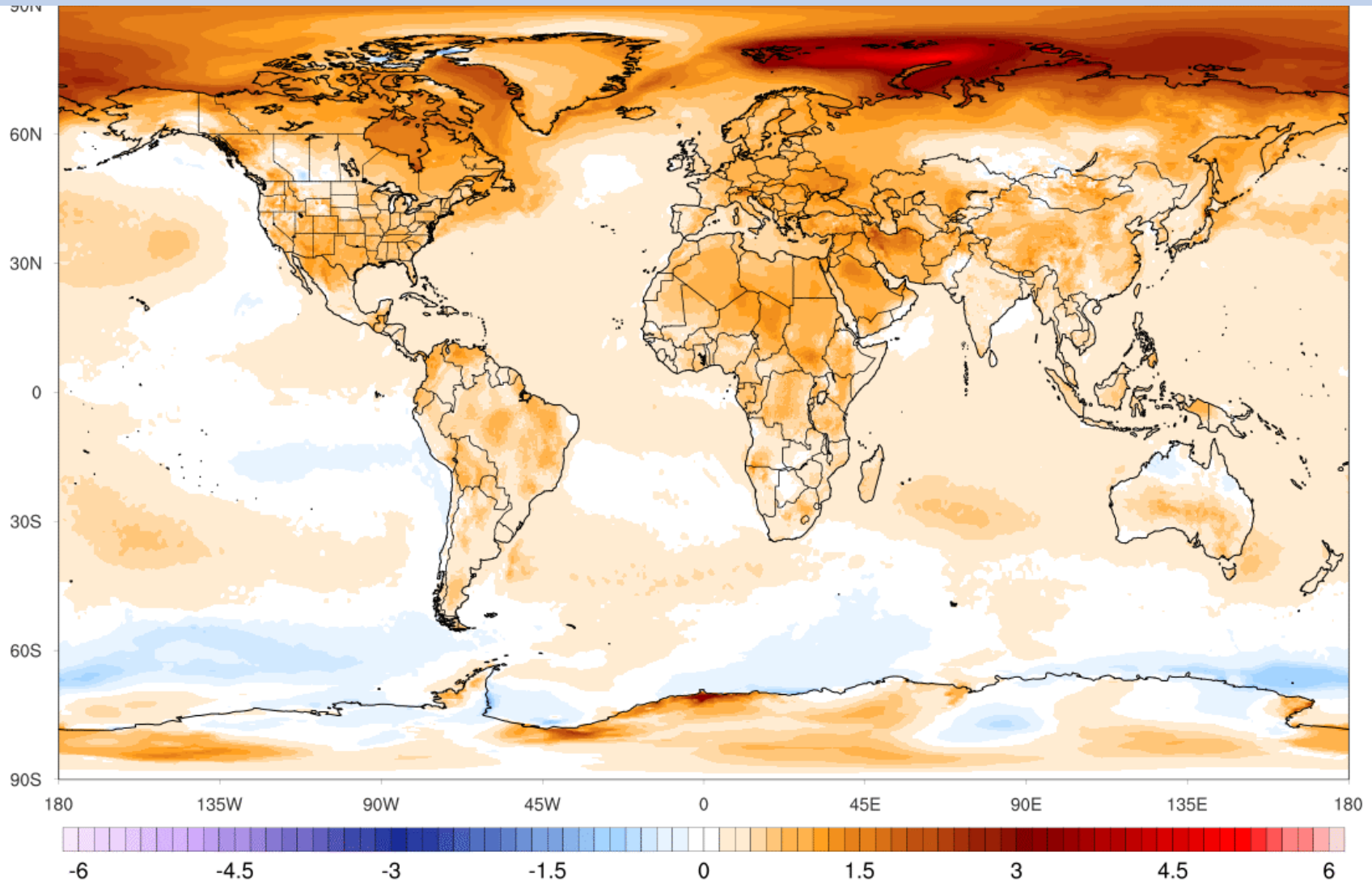


AD900 Mayan Collapse

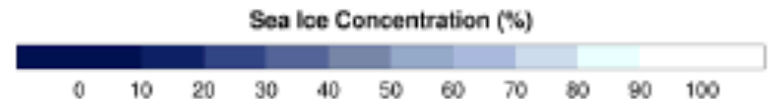
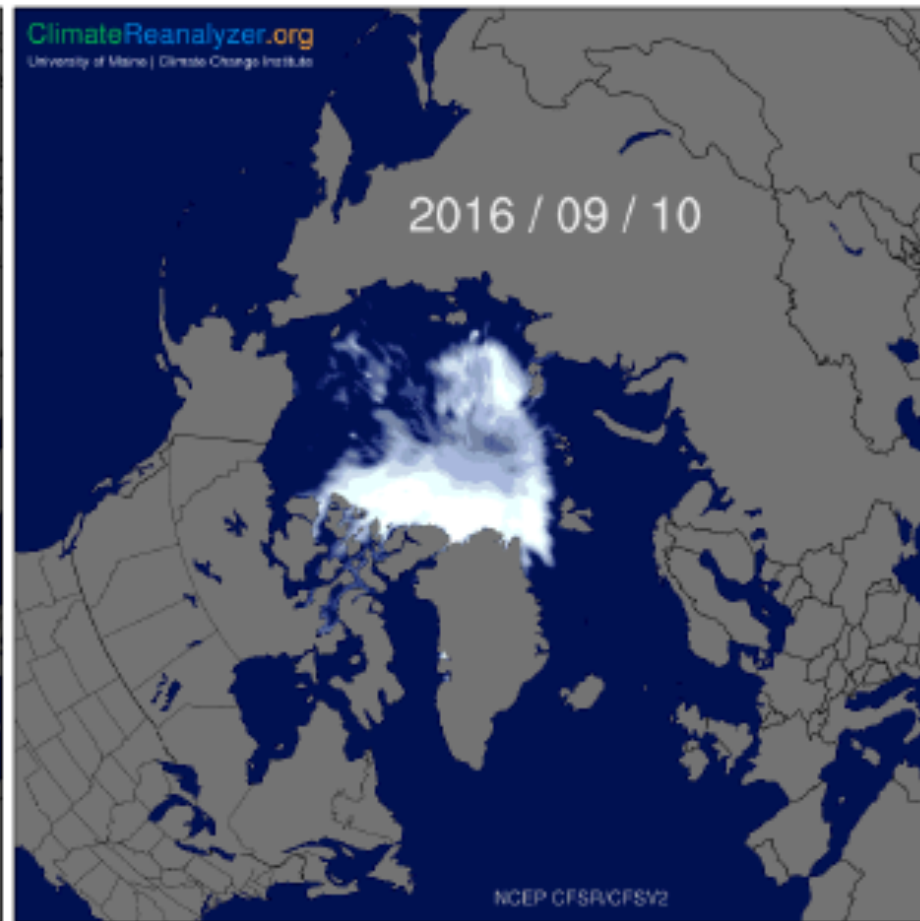
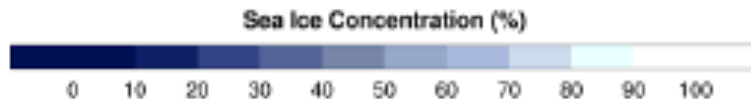
(Mayewski and White, 2002)



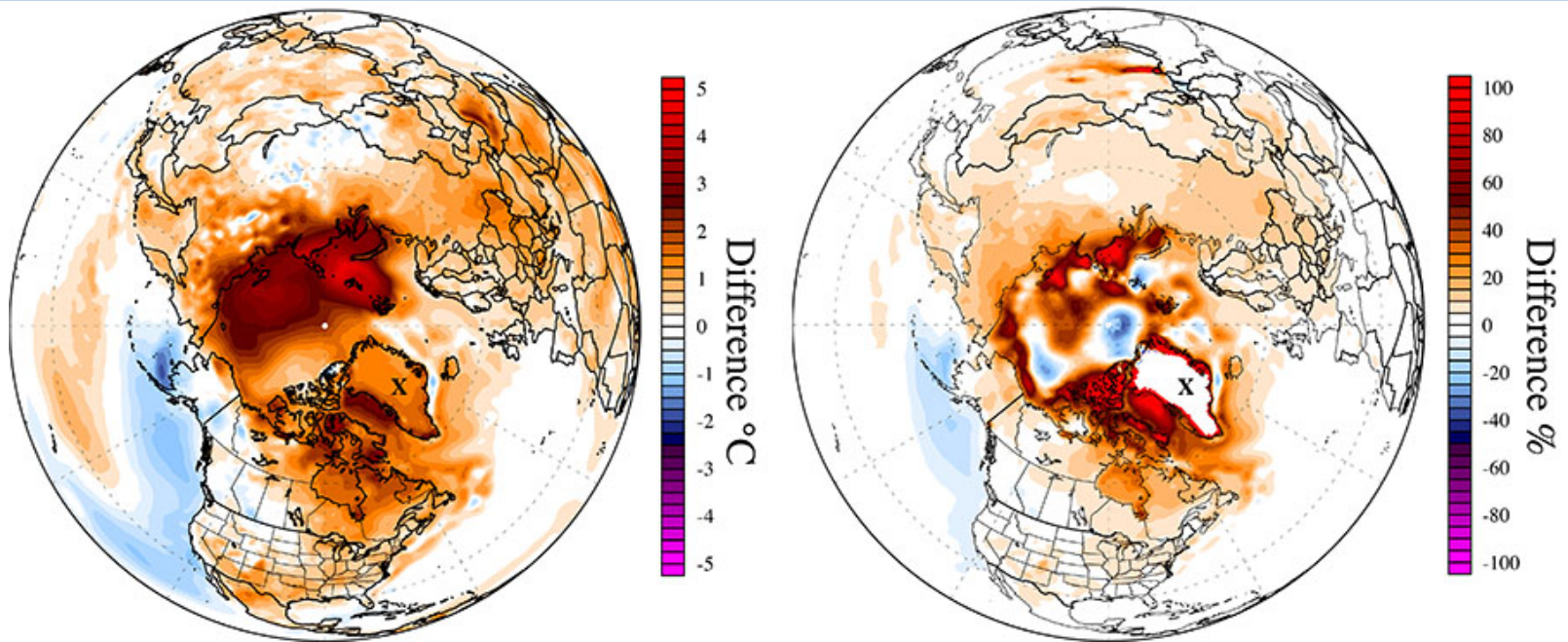
The evolution of warming 2005-2018 compared to 1979-2004



A new ocean emerges Faster than expected!



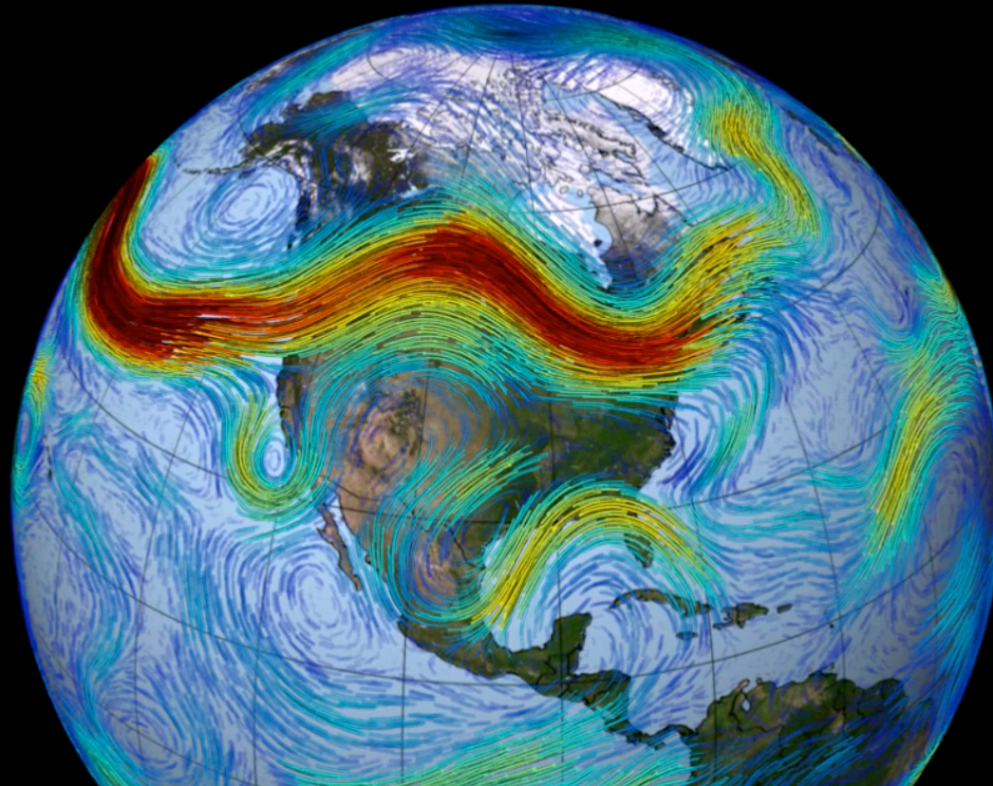
Abrupt climate change
up to $+5^{\circ}\text{C}$ ($+8^{\circ}\text{F}$)
doubling of summer length
as of 2007 to 2012



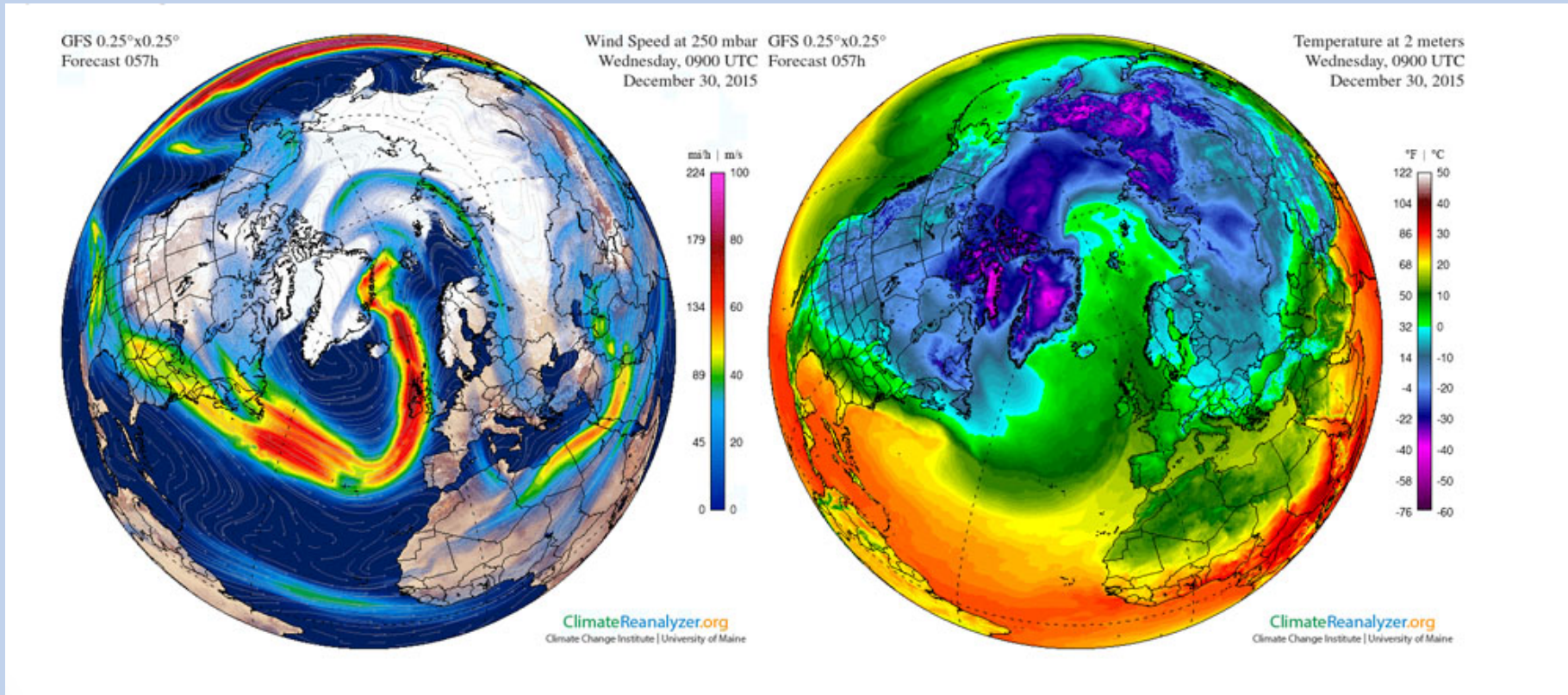
Mayewski et al. (2013)



*Arctic warming changes
the shape and strength of the jet*

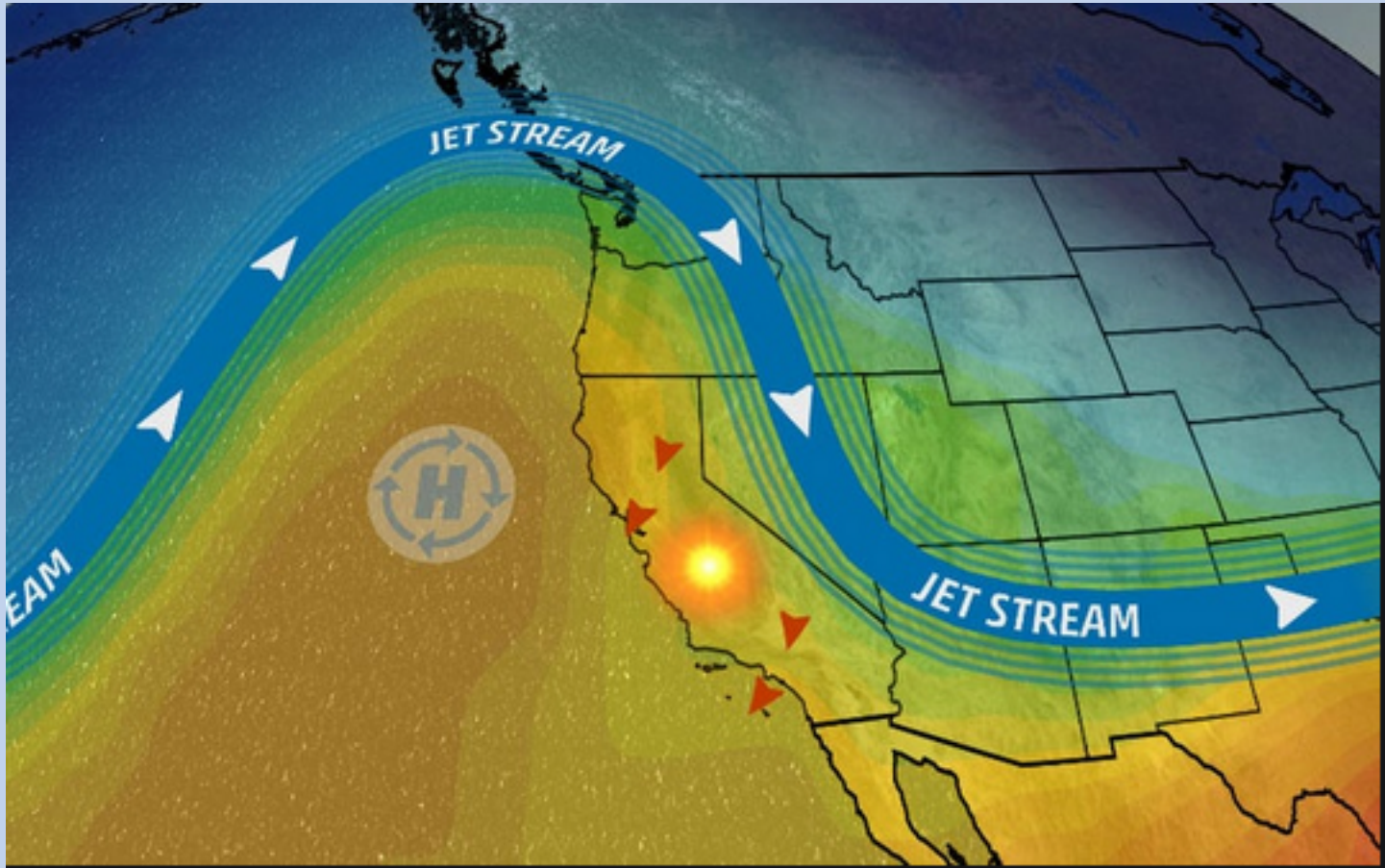


Extreme events – North Pole



North Pole above freezing mid-winter
several times since 2014

Extreme events - Wildfires



Jet Stream path pushes high winds and dry air into California

*Air masses transport:
cold/warm
wet/dry
pollutants
surface ocean currents*



10-km GEOS-5 Aerosol Optical Depth

Dust | Organic & Black Carbon | Sulfates | Sea Salt



Drilling into Greenland's ice to track pollution

Clean Air legislation is effective



(Mayewski and teams 1980s, 1990s)



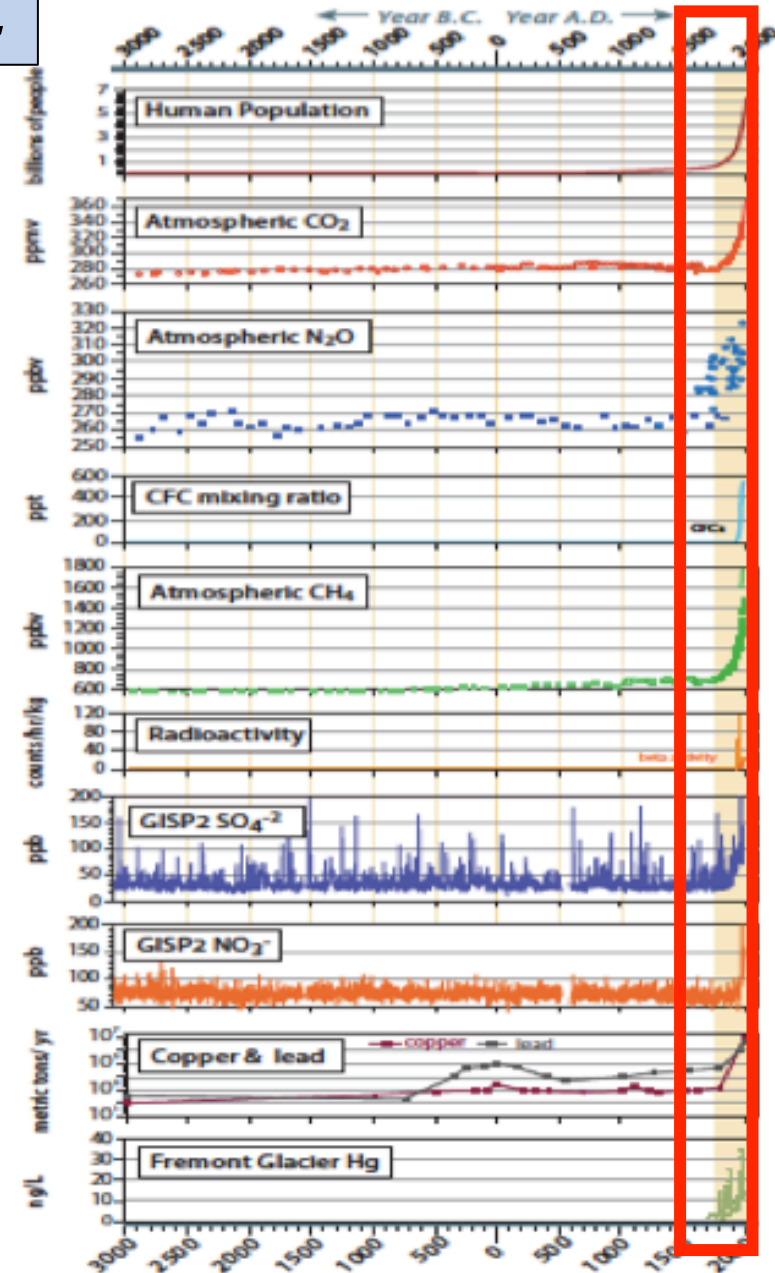
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Undeniable human impacts.

Greenhouse gases
Acid rain
Toxic metals
Organic acids
Engineered chemicals
Radioactivity
Particulates
And much more!!!



The “toxic climate cocktail”



Warming

(vector borne diseases,
drought, flood, storms)

Respiratory

Neurological

Cancer

Ecosystem upheaval

(ocean acidification, drought,
flood, invasive species)

*1 in 10 deaths worldwide
attributed to air pollution*



*7 million premature
deaths per year*

The wild card
Arctic warming is releasing
methane trapped in the Arctic



A basis for assessing and predicting climate change for Maine



**2015
UPDATE**



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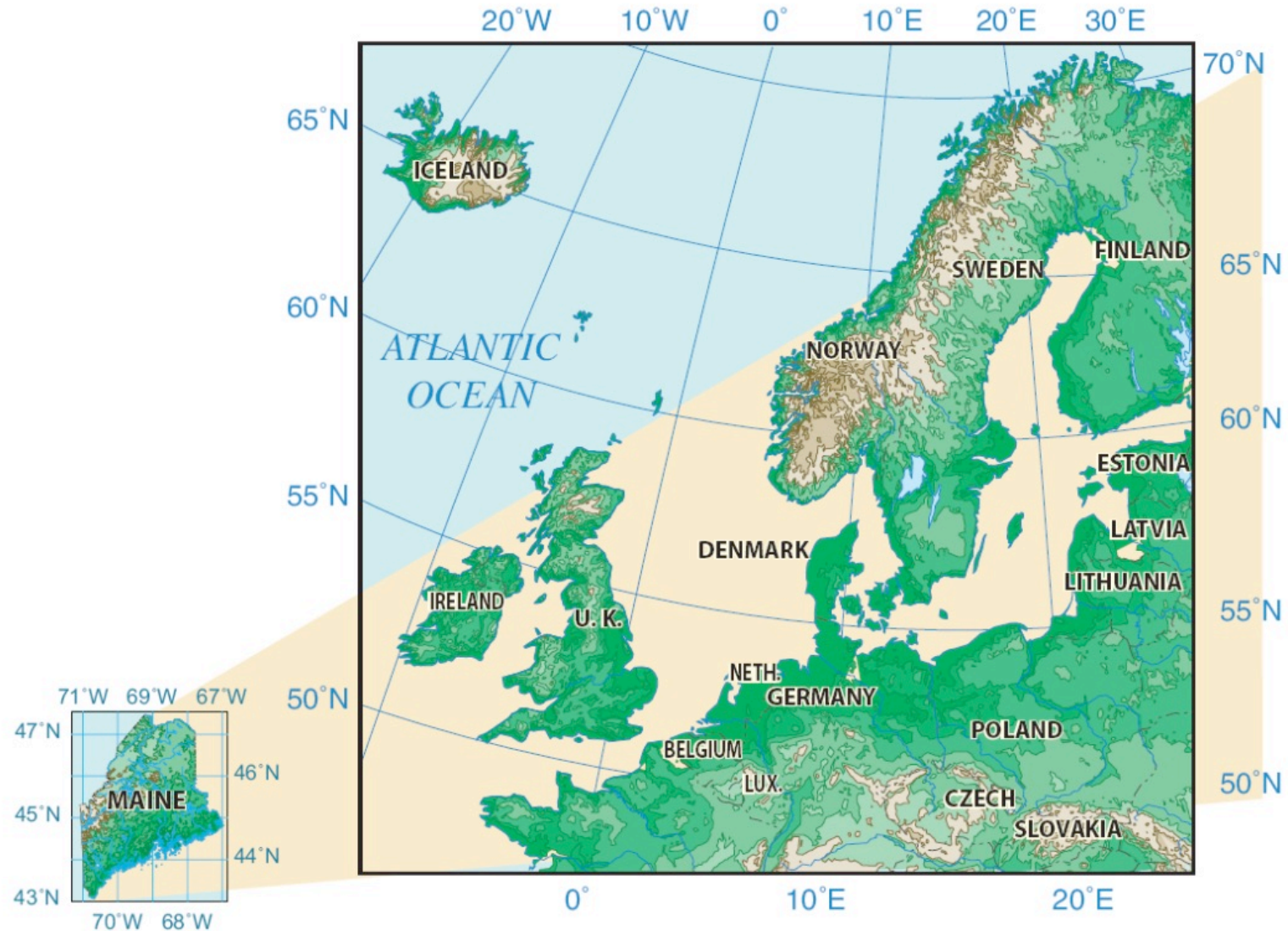


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COASTAL MAINE
CLIMATE FUTURES 2019



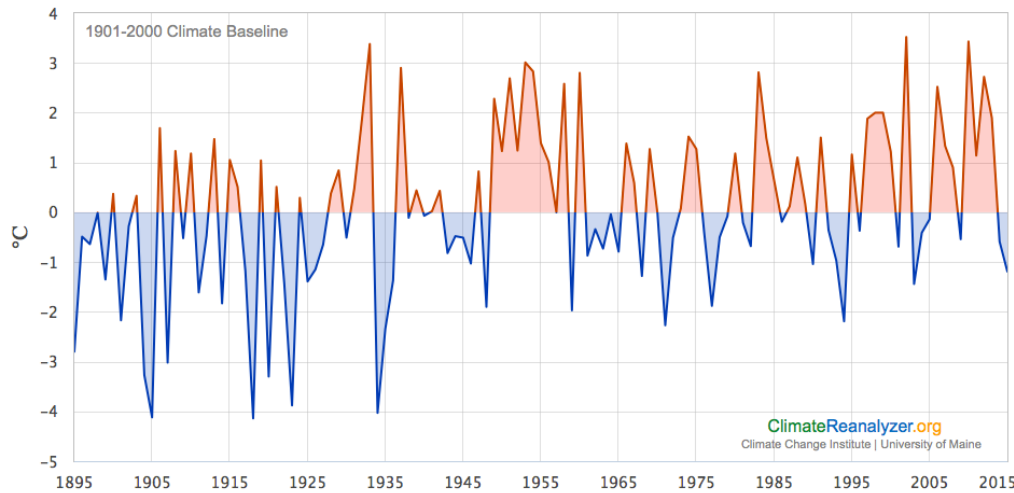
Maine has a diverse range in climate



Maine's Coldest Winters

Maine, USA Winter (DJF) Avg. Temperature Anomaly

Data Source: PRISM Climate Group, Oregon State University, <http://prism.oregonstate.edu>



Penobscot Bay

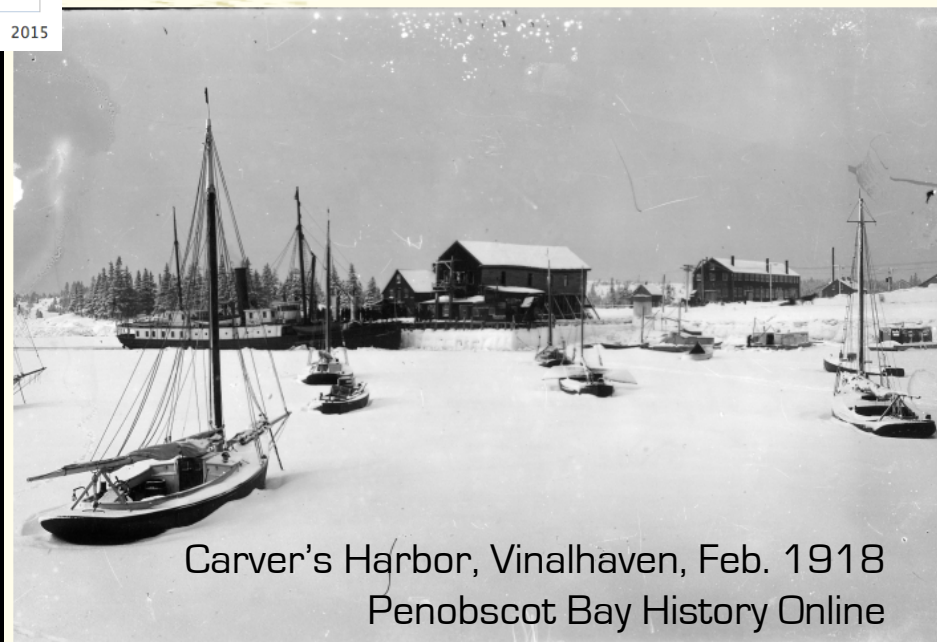
Freeze-overs:

1904, 1905,

1918, 1923,

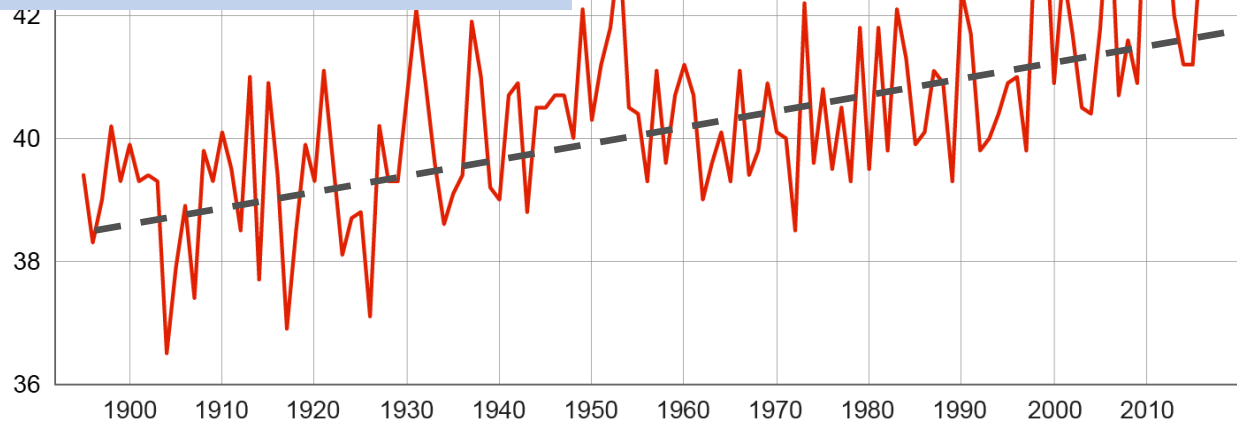
1934 (major)

1971 (moderate)



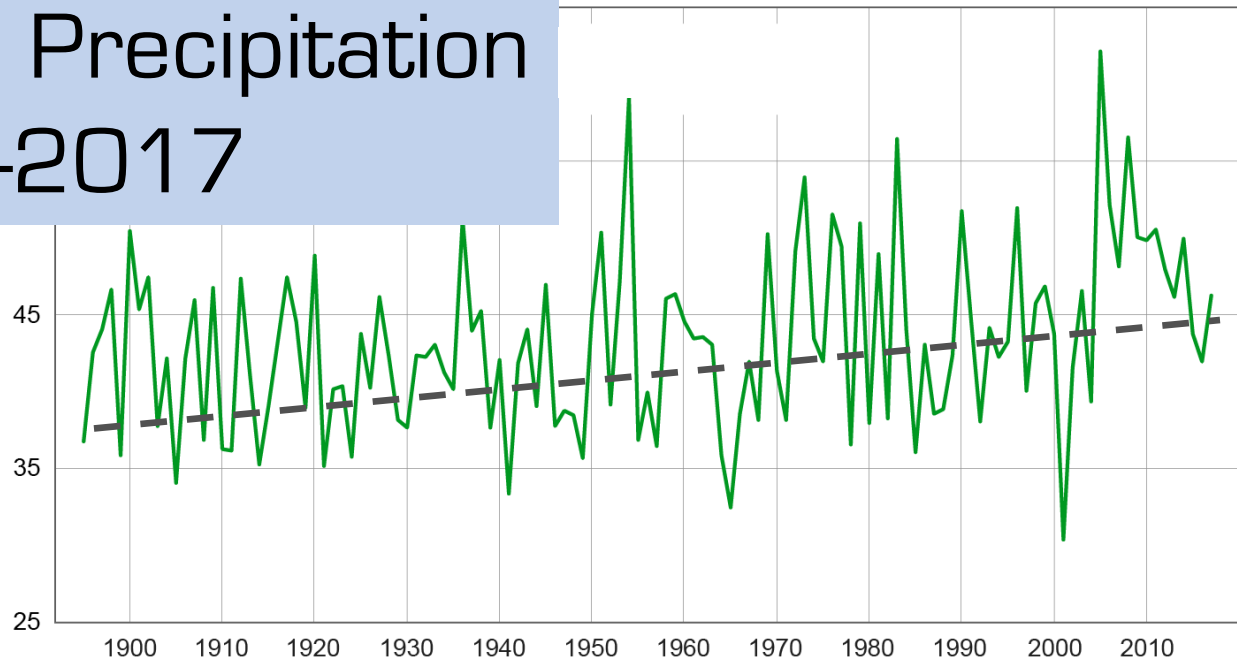
Carver's Harbor, Vinalhaven, Feb. 1918
Penobscot Bay History Online

Maine Temperature 1895-2017



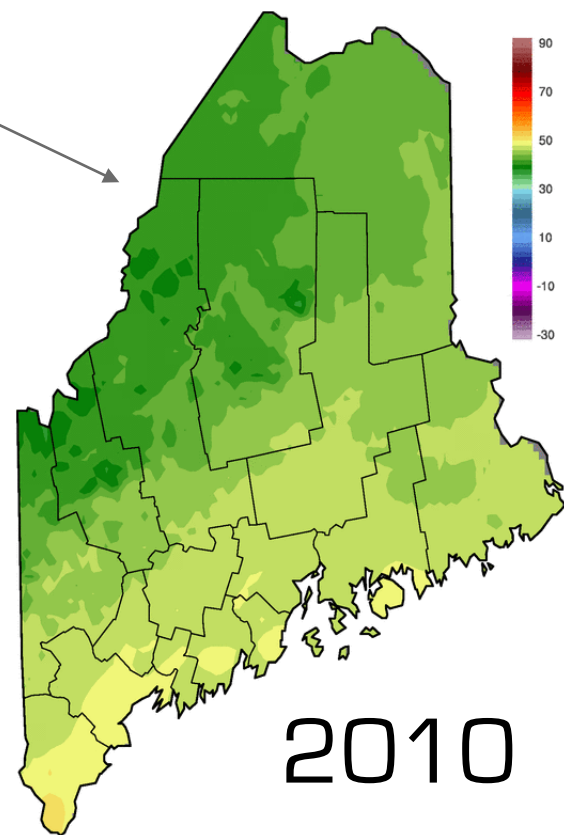
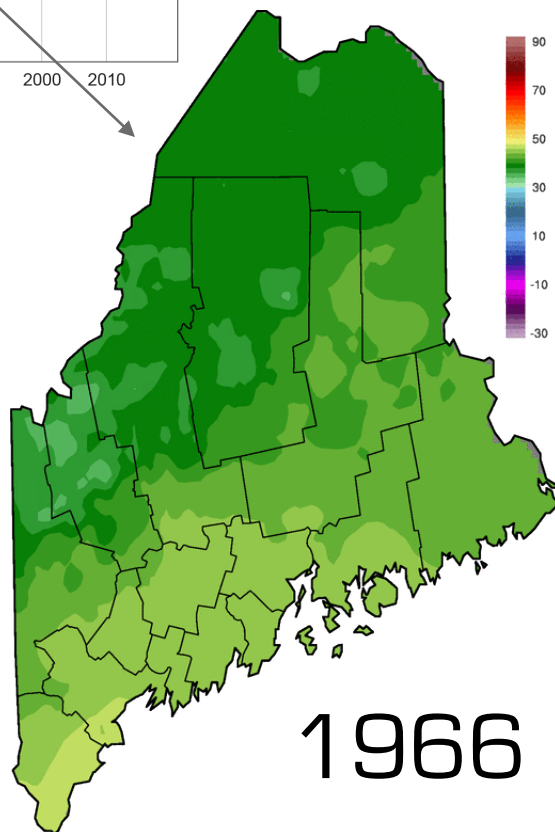
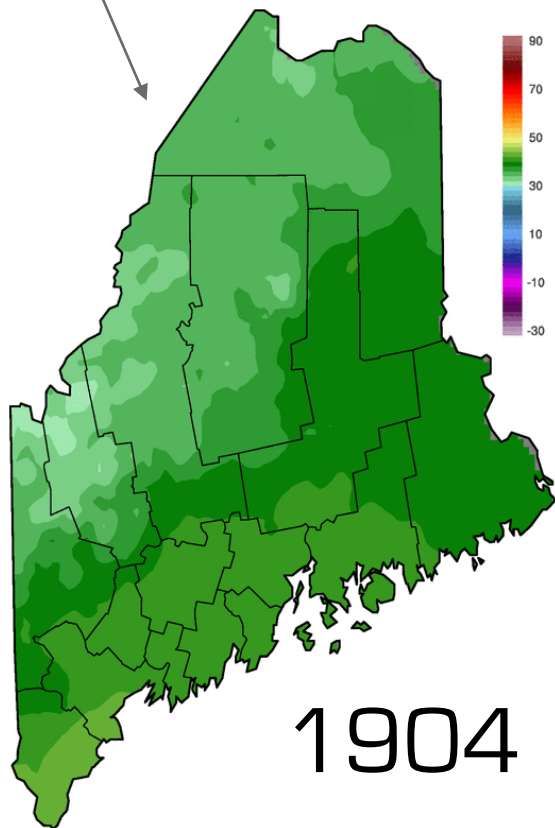
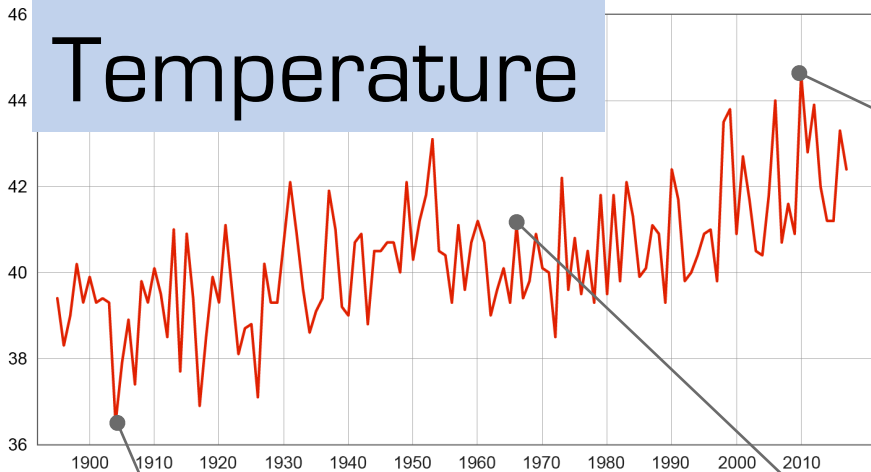
+ 3°F

Maine Precipitation 1895-2017



+ 6 in

Temperature

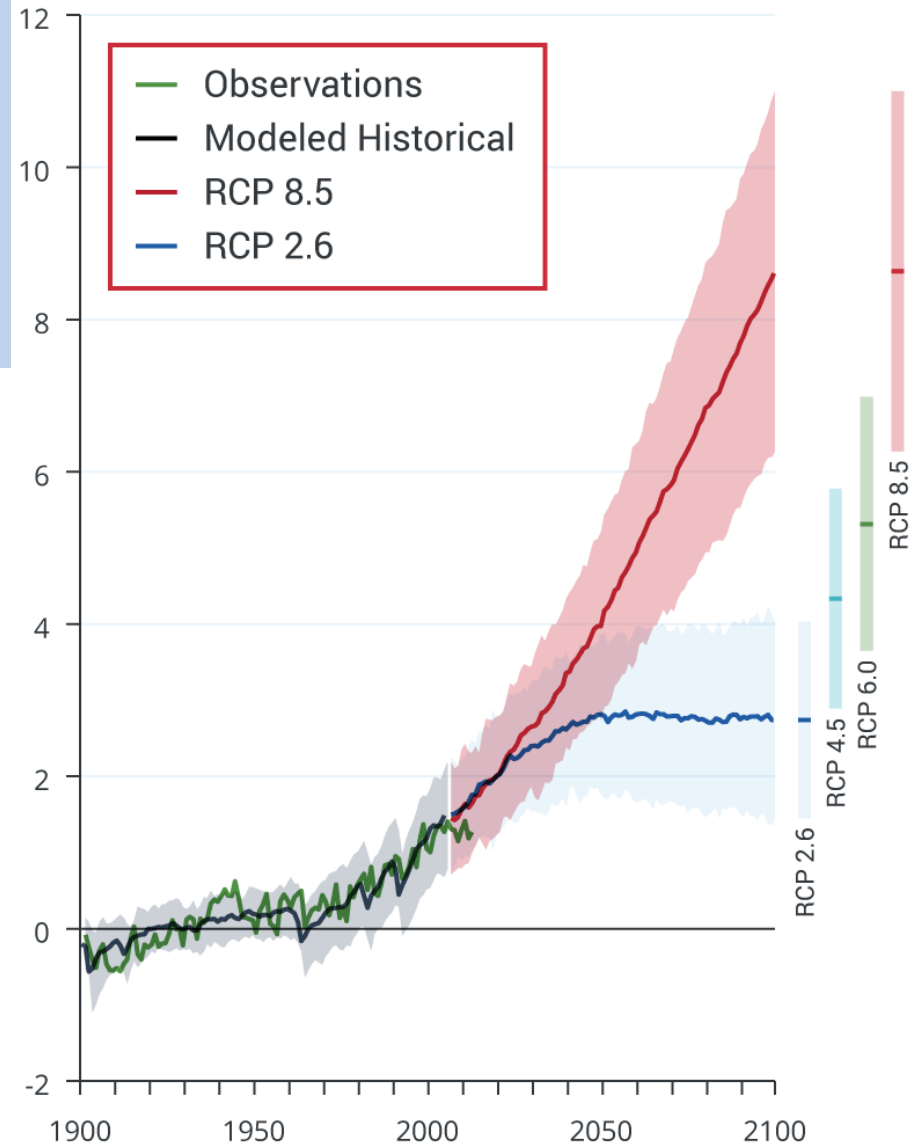


Maine - Observed Impacts

- Increased growing season length
- More heat waves and seasonal drought
- Frost/freeze timing in spring and fall
- More ice and wind storms
- Increased storm intensities, coastal erosion, sea level rise approx. 7" since 1900
- Runoff/flooding increase
- Reduced winter snow
- Northward spread of invasive plants/pests

*Predictions for Maine
based on climate models*

*Future climate based
on numerical models
physics, CO_2 ,
global view,
linear trend*



By 2030 - 2050
Maine's temperature will rise 3°F
- as much as it has since 1900

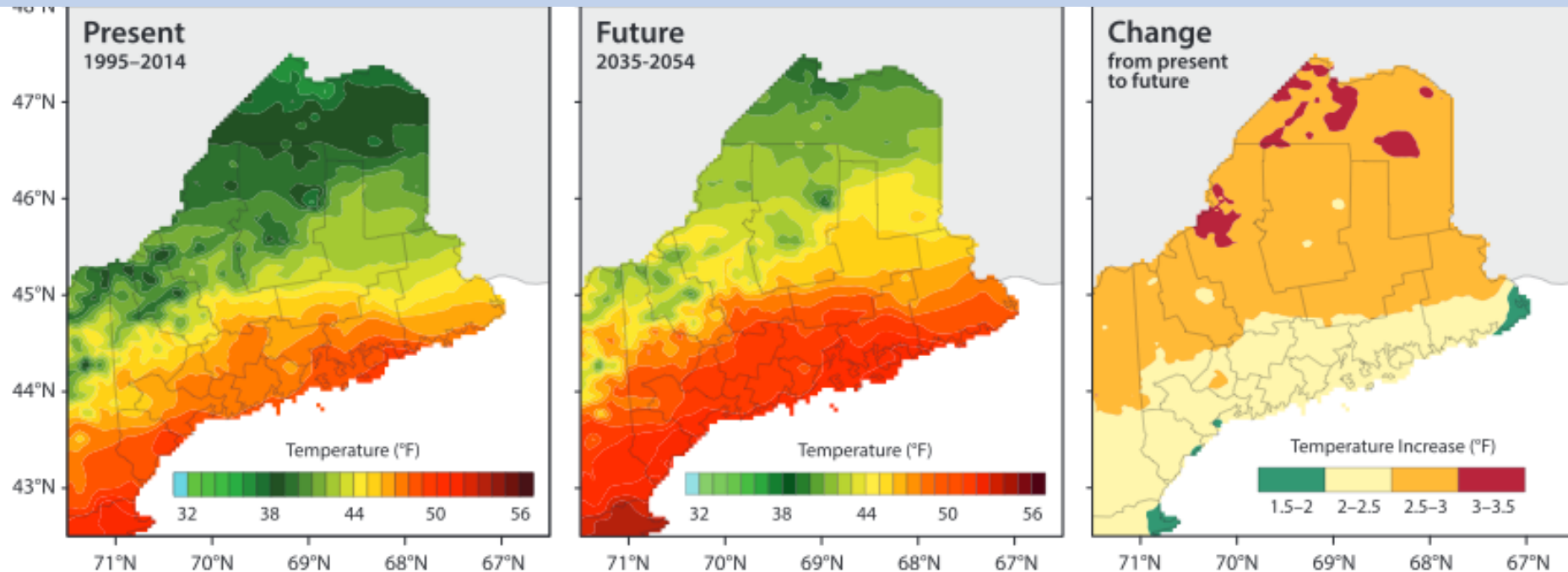
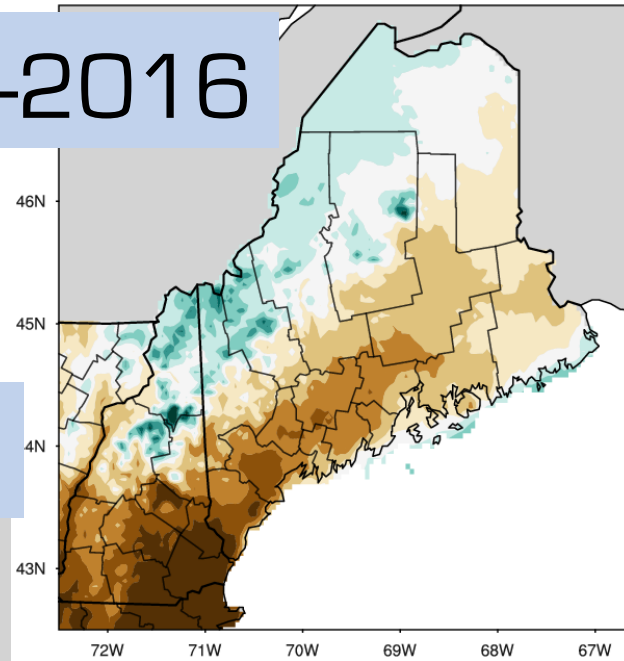


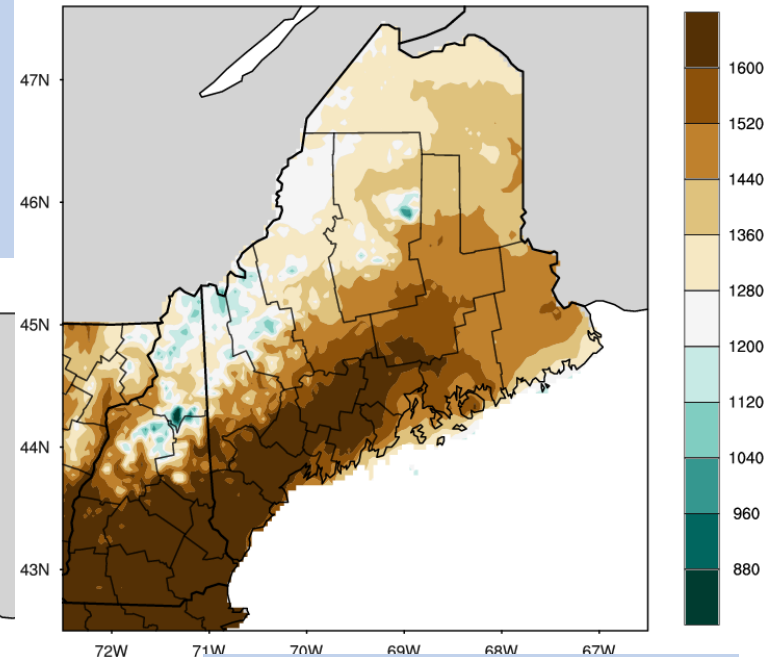
Figure 2. Maps showing mean annual temperature for 1995–2014 (left), 2035–2054 (center), and the predicted change or difference between the two time periods (right). The predicted rise in temperature by 2050 ranges 2.0–3.0 °F from the coast inland to the Canadian border. Maps derived from an ensemble simulation of the IPCC A2 emissions scenario.¹

Longer summers and shorter winters drive Lyme tick habitat expansion

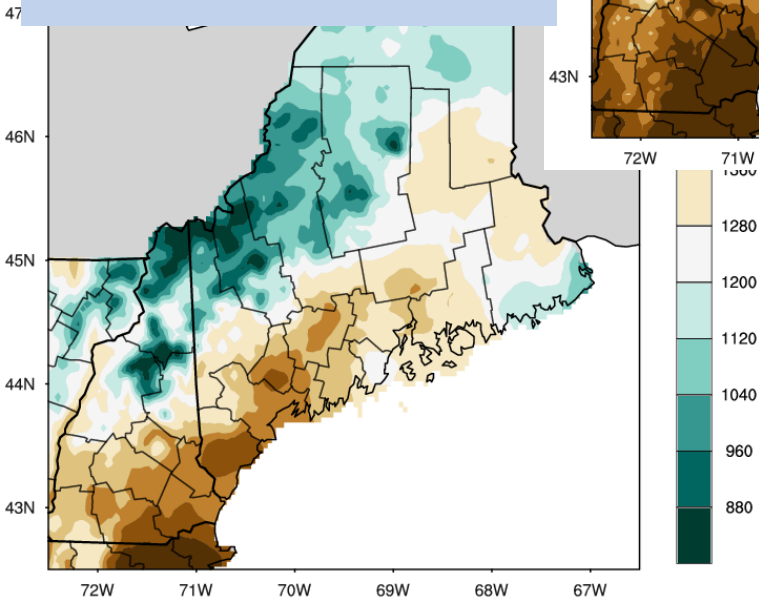
2010-2016



Jan-Aug Degree-Day Accumulation [6°C base]



1980-1989

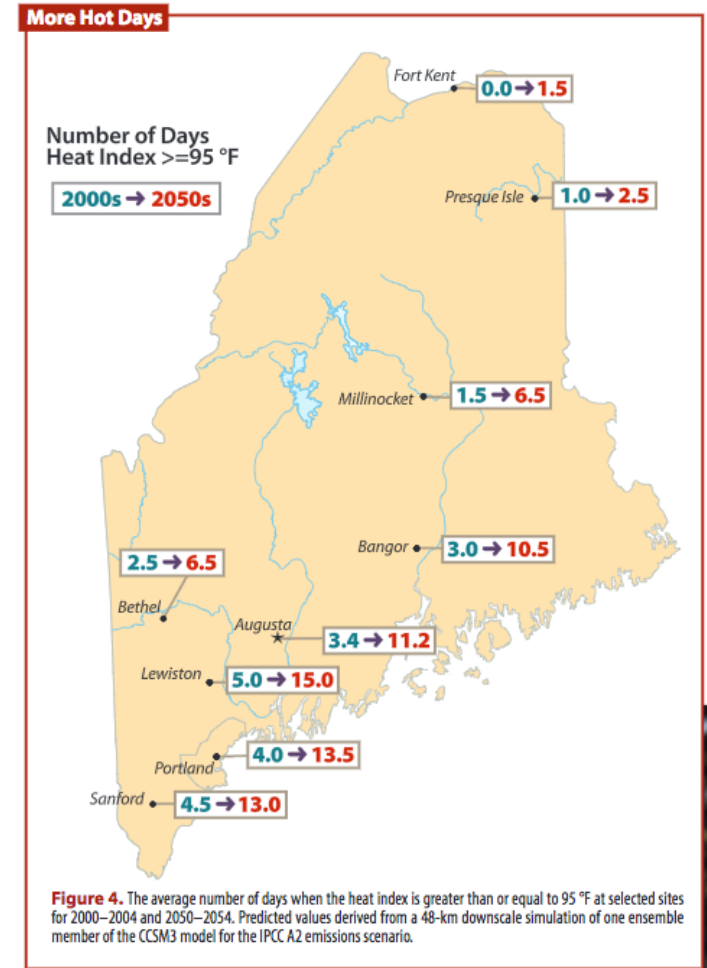


2040-2049



Heat illness admissions to hospital double when temperatures go from 74 - 79°F

The number of days
more than 95°F
will triple by mid-century



*By 2035 – 2054
precipitation increase
will be the same as the
increase over the
past 125 years*

Another 6"

Maine's Total Annual Precipitation

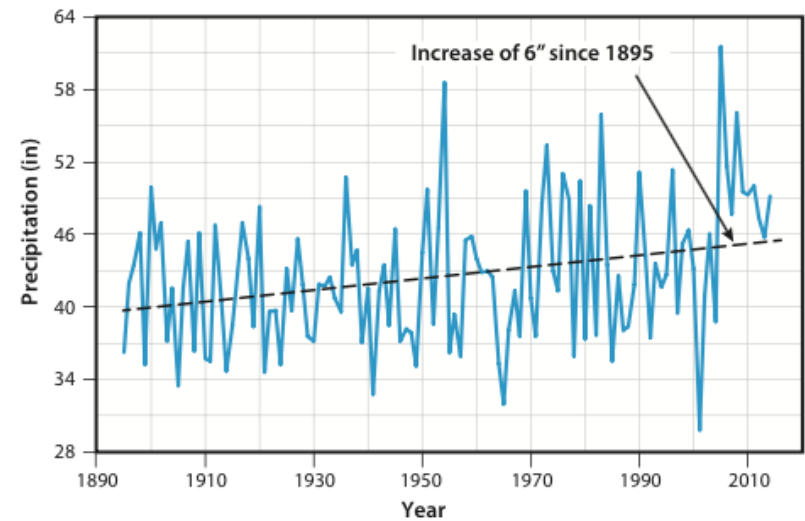


Figure 6. Total annual precipitation, 1895–2014, averaged across Maine from gridded monthly station records from the U.S. Climate Divisional Dataset (ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php). A simplified linear trend (black line) indicates that precipitation increased six inches, or about 13%, during the recording interval.

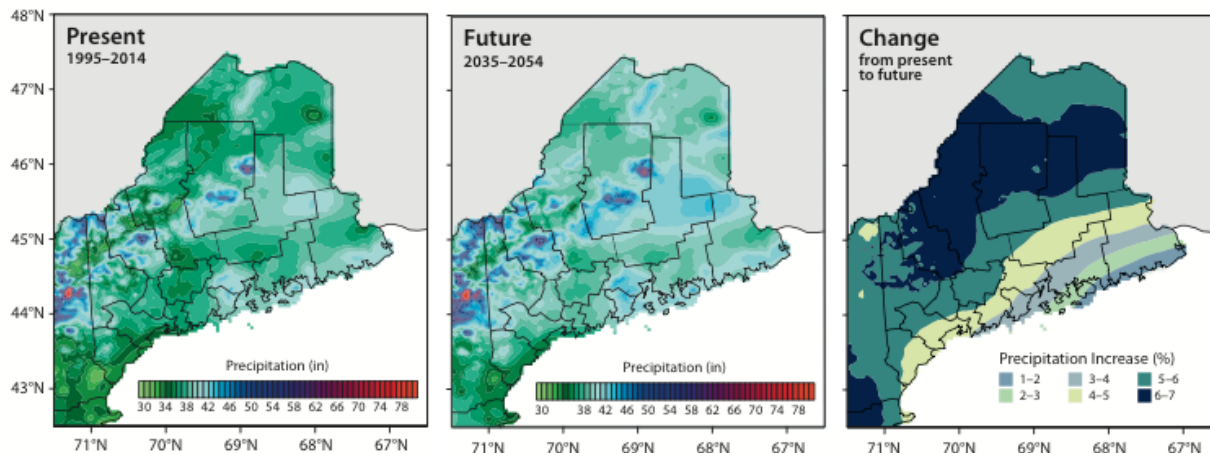


Figure 7. Maps showing total annual precipitation for 1995–2014 (left), 2035–2054 (center), and the predicted change or difference between the two time periods (right). The predicted precipitation increase by 2050 ranges 1–7% from the coast inland to the Canadian border. Maps derived from an ensemble simulation of the IPCC A2 emissions scenario.



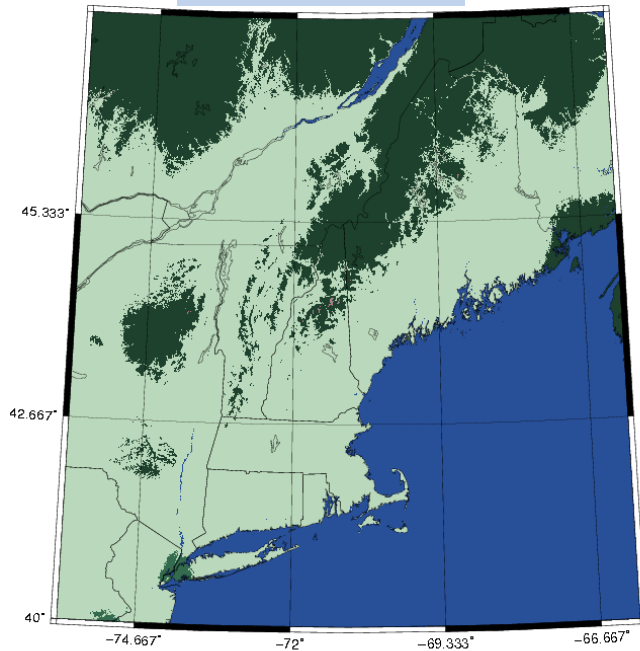
Northward shift of forest biomes

Boreal → Mixed → Broadleaf

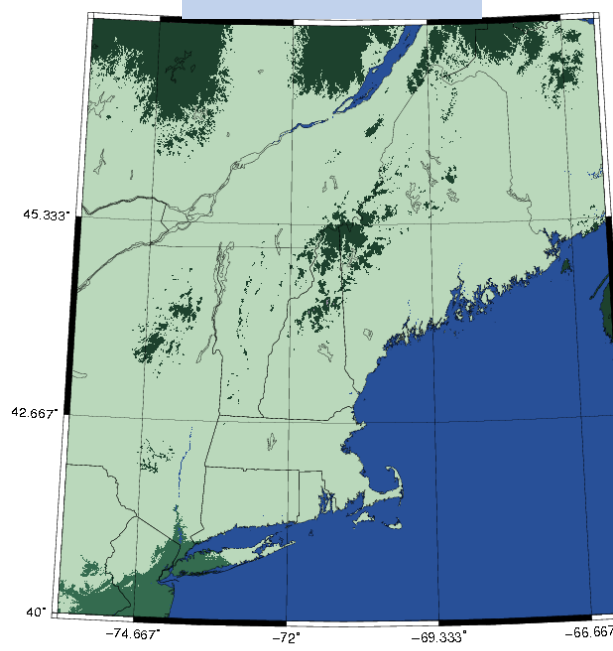
1850

2000

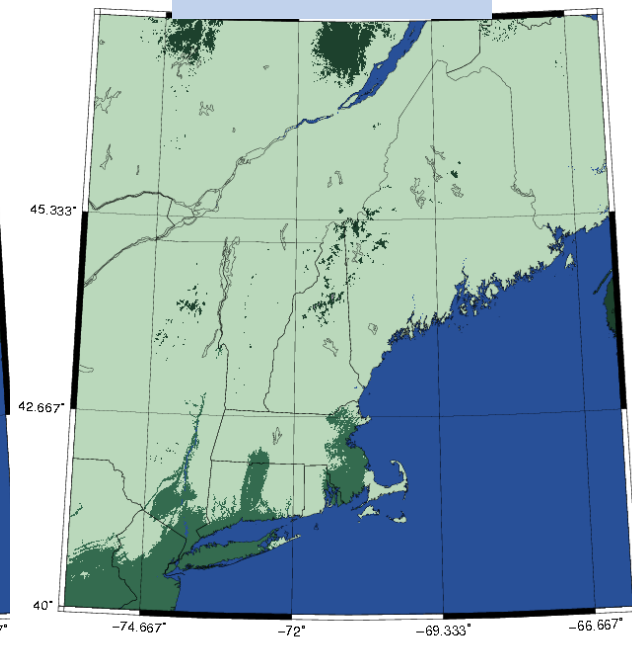
2050



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ENVIRONMENTAL CHANGE MODEL



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ENVIRONMENTAL CHANGE MODEL

Environmental Change Model (Birkel)

*Predictions based on
climate models
plus modern analogs
yield:
local to regional scale,
variability,
and impacts*

Gulf of Maine temperatures and ocean acidification will continue to rise and impact fisheries

Gulf of Maine Sea Surface Temperature

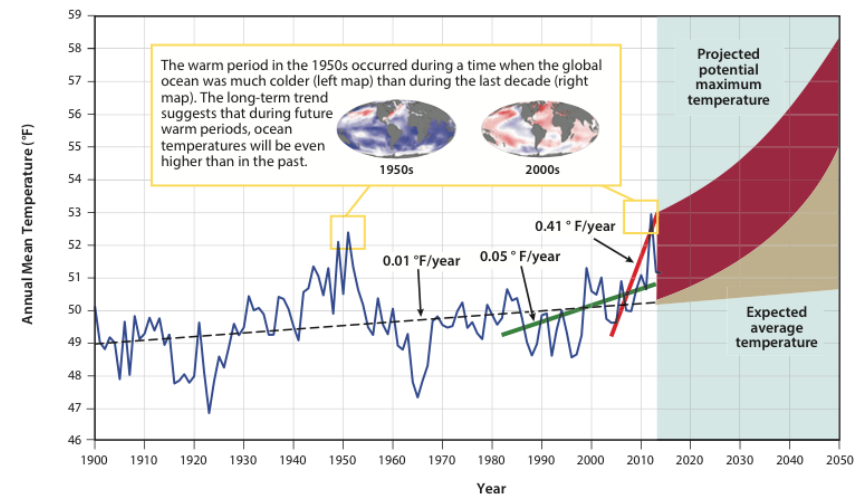
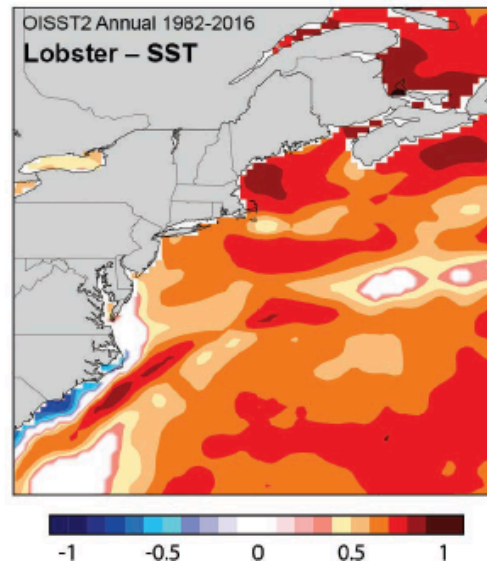
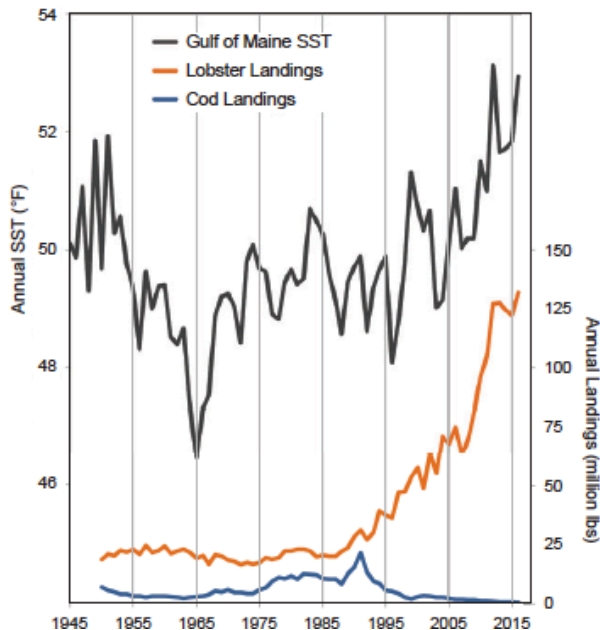
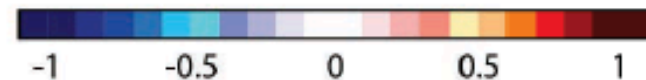
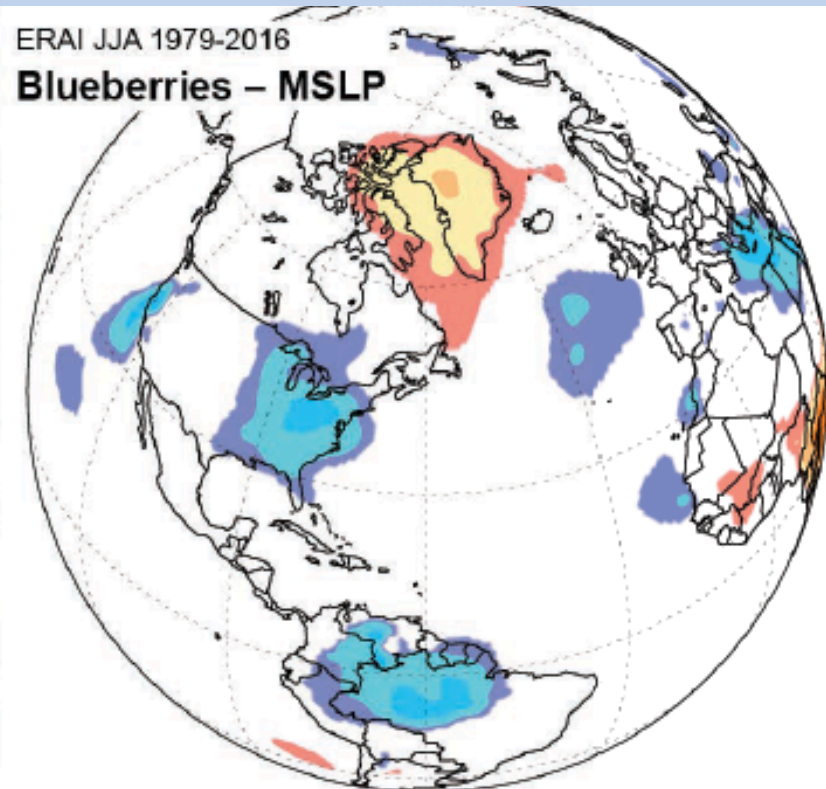
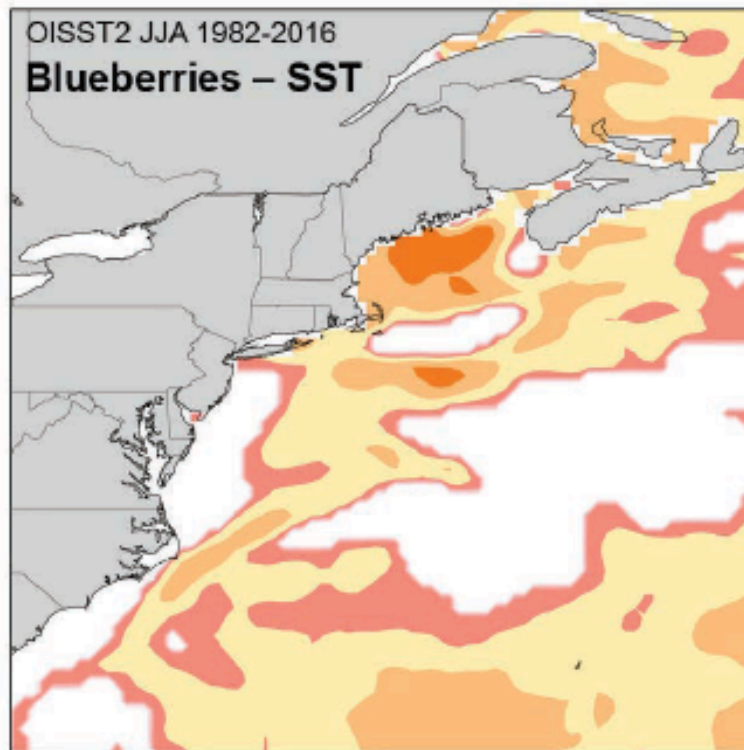


Figure 12. Mean sea surface temperature in the Gulf of Maine from 1900 to 2014 (blue), based on Extended Reconstructed Sea Surface Temperature (ERSST) version 3b data provided by the NOAA/GAR/Earth System Research Laboratory Physical Sciences Division, Boulder, CO (ersst.noaa.gov/psd/). The temperature trend over the entire record is 0.01 °F per year (black line). The rate accelerated to 0.05 °F per year after 1982 (green line) and was 0.41 °F per year from 2004–2013 (red line), based on NOAA Optimum Interpolation 1/4 degree daily sea surface temperature analysis of future mean temperatures (red and tan area), with the range driven by the uncertainty in how much carbon dioxide and

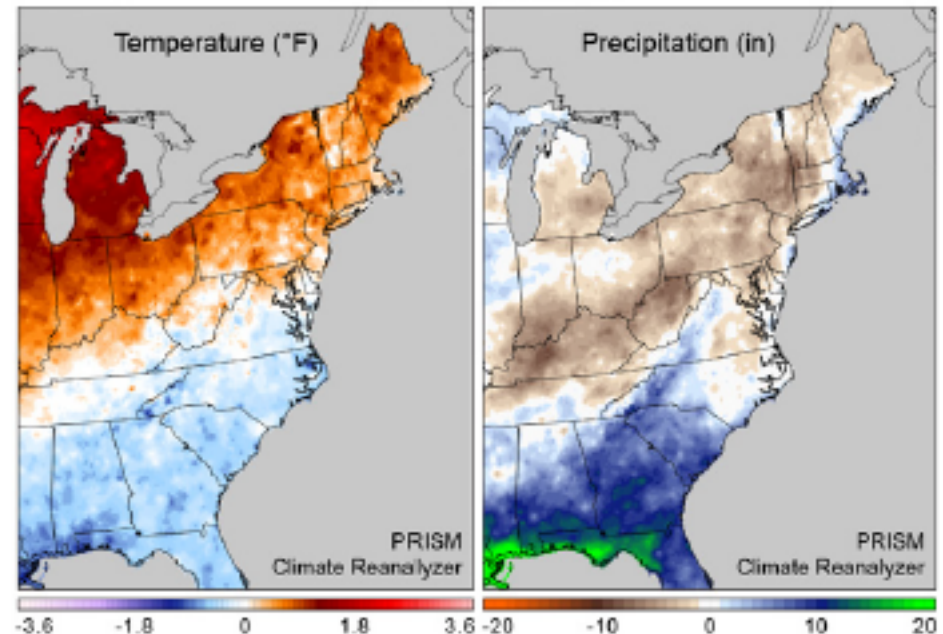
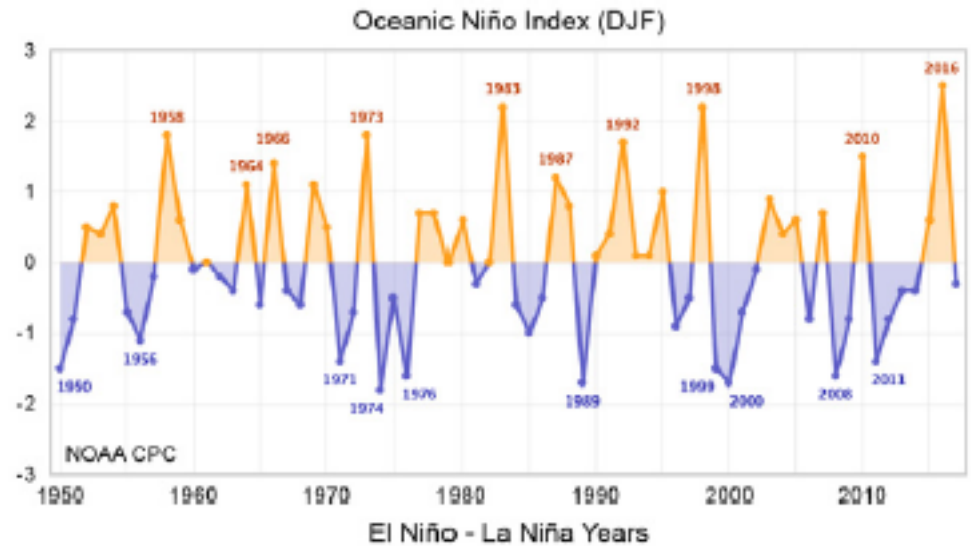


Lobster
mortality $\sim 68^{\circ}\text{F}$
Wahle et al., 2015

*Blueberry yield increases as summer
Gulf of Maine sea surface temperatures
increase and more rain moves onshore*



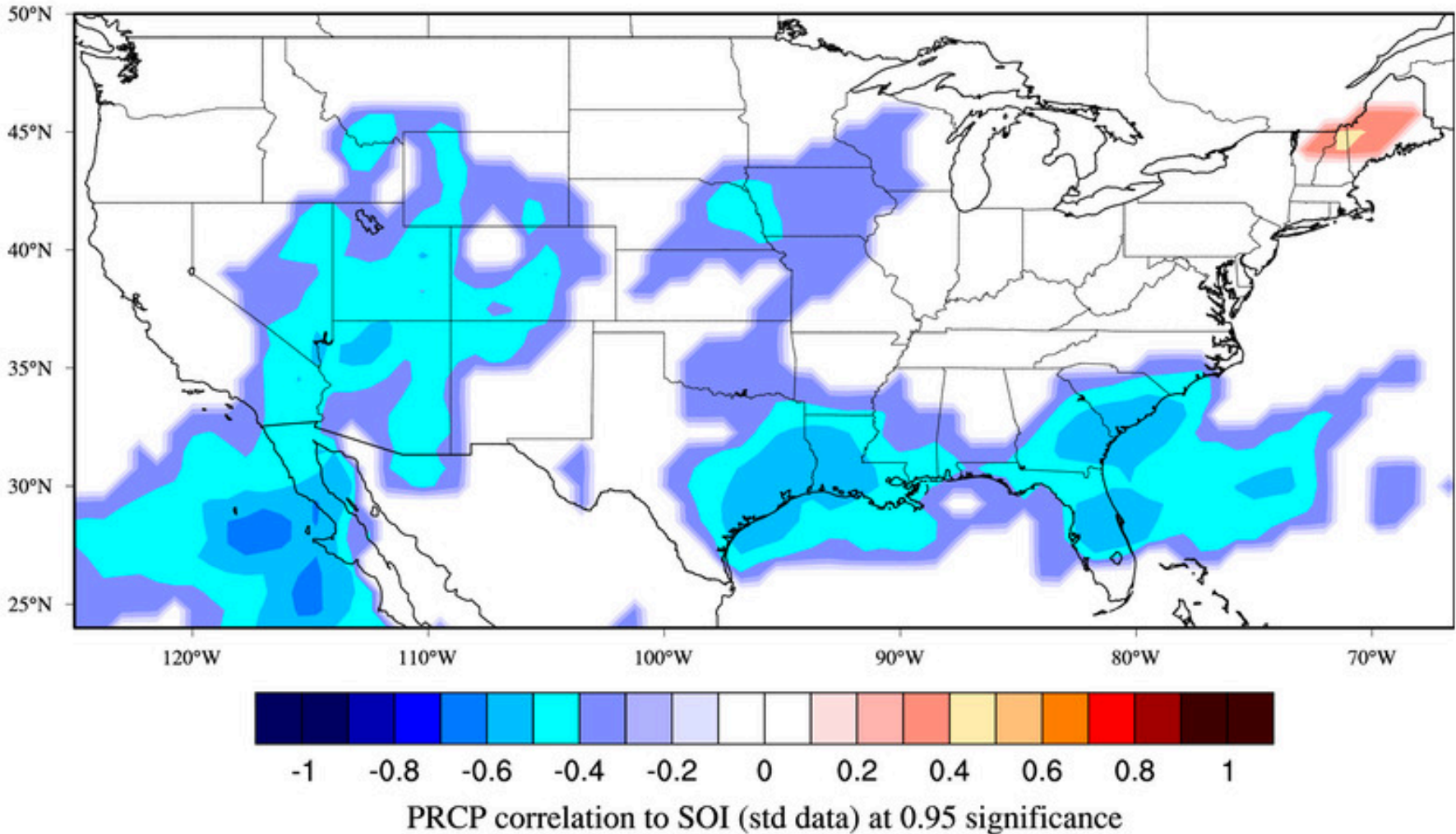
*During El Niño
when the
Pacific Ocean
is warmer
Maine is
drier and warmer*



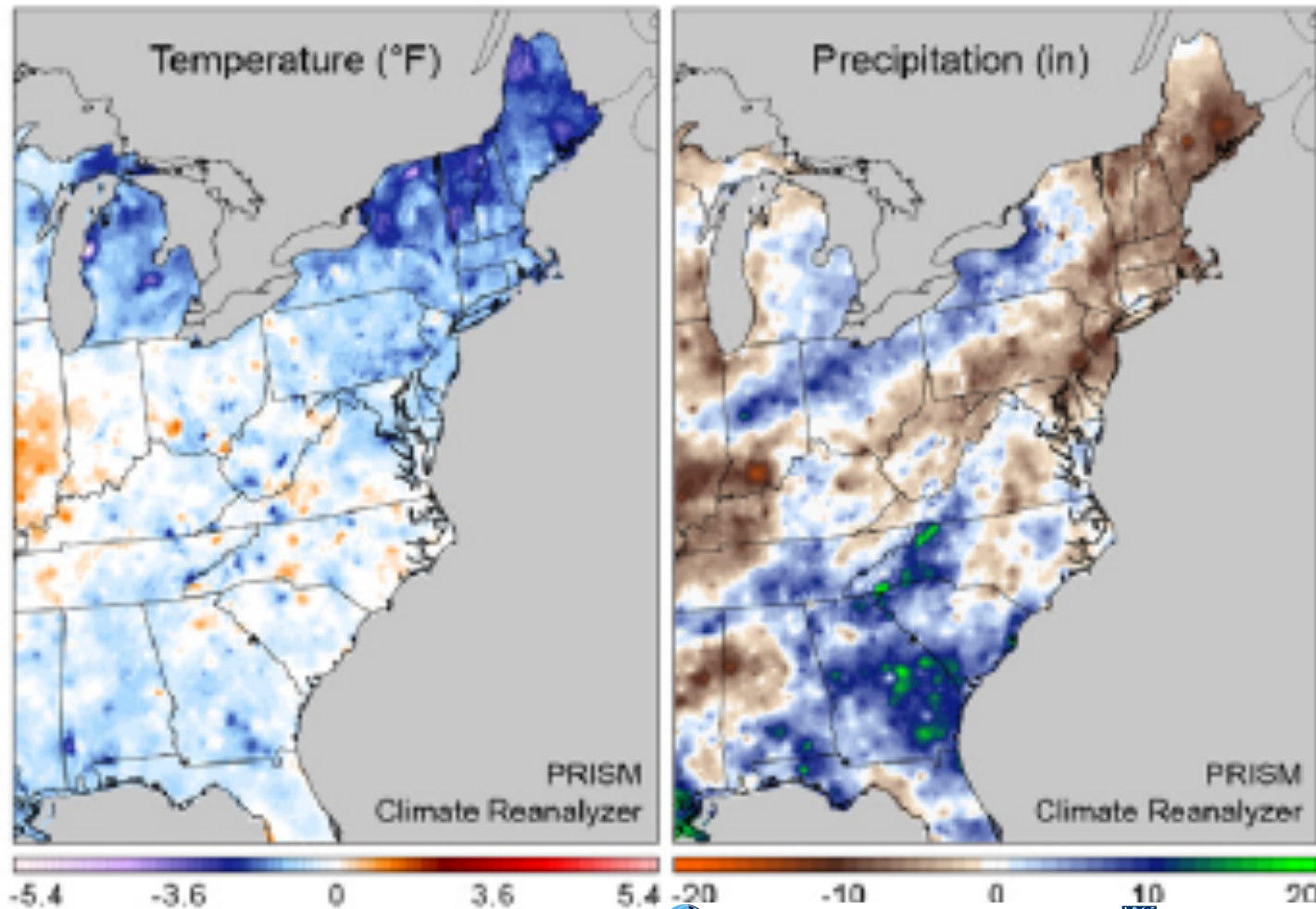
Unlike most of the rest of the US

ERA-Interim

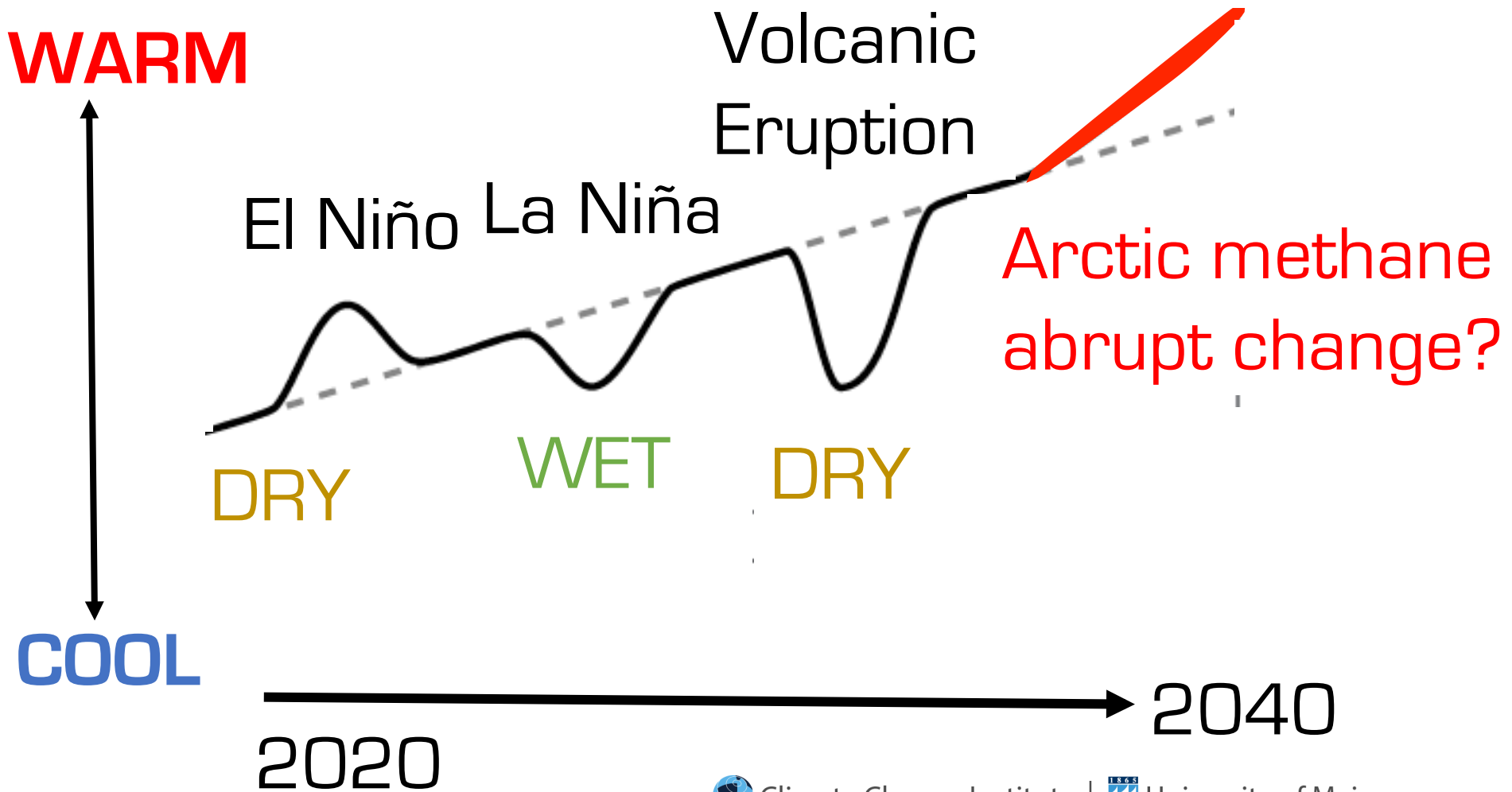
Annual 1979-2017



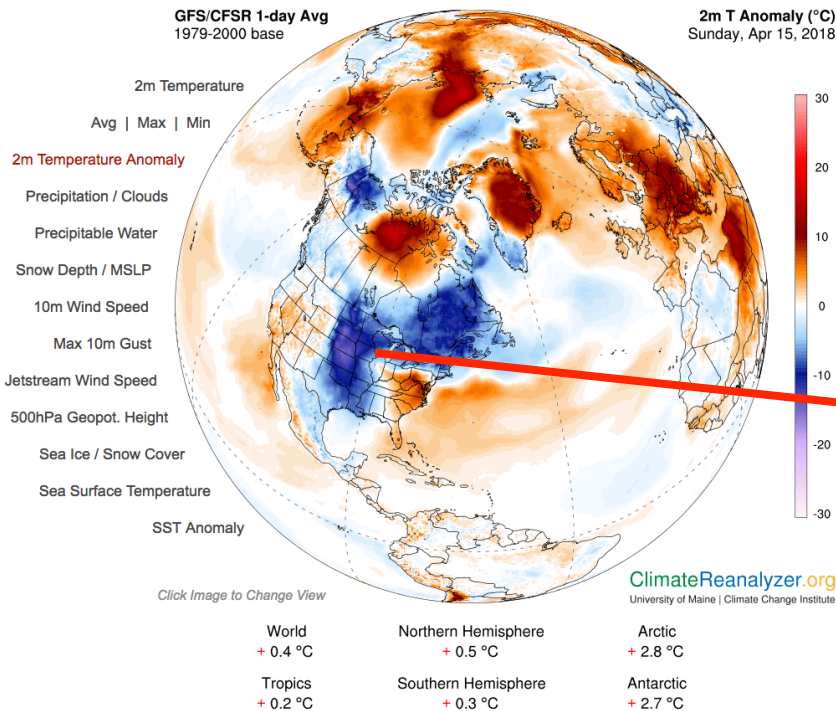
BY 2040 we will likely have another volcanic event like Pinatubo (1991-92) and NE US will be cooler and drier for 1-2 years



Plausible scenarios for Maine superimposed on current warming trend

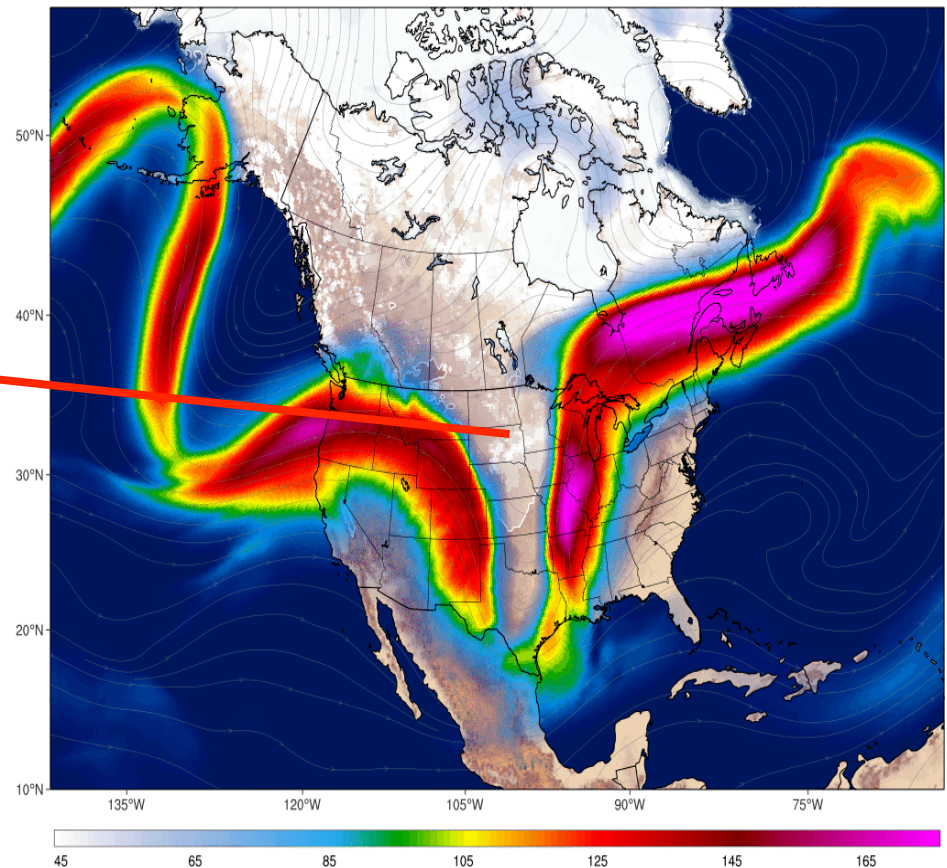


Changes in the shape of the Jet Stream will continue to create instability and extreme events



GFS 250hPa Wind Speed (mi/h), Snow Cover, Sea Ice
Init 2018/04/15 00Z | f000 Valid Sun 00Z, Apr 15, 2018

ClimateReanalyzer.org
University of Maine | Climate Change Institute



Climate change impacts



Climate change impacts



Health and Resource Depletion

Warming (heat stress, vector borne diseases)

Pollutants (respiratory, neurological) acidification, agriculture, forestry (bio-limits)

Extreme events (drought, flooding, storms, heat stress)

Ocean acidification

Water, air, food, oil

Ecosystem resources



Climate change impacts



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Economy

Personal finances

Energy (consumption, efficiency, renewable)

Technology

Redistribution and depletion of resources

Innovation and job opportunities

Globalization vs regionalization



Climate change impacts



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Catastrophes

Extreme events (drought, flooding, heat stress)

Storm surges and sea level rise

Food supply (physical and chemical impacts)

Climate change refugees

Response capability



Climate change impacts



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Geopolitics

Ice free Arctic Ocean

Energy dependence

Water tower countries

Climate refugees

Developed vs developing country blame



Maine's Potential

Natural resources
water (El Niño, volcano),
forests (CC), marine (Mgmt)



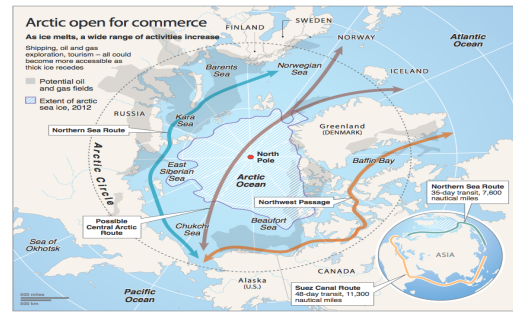
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Reduced pollution (ghg/toxics)



Maine's Potential

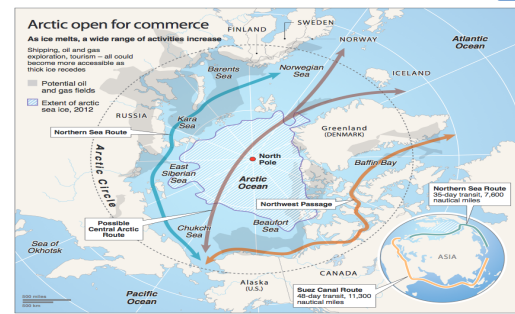
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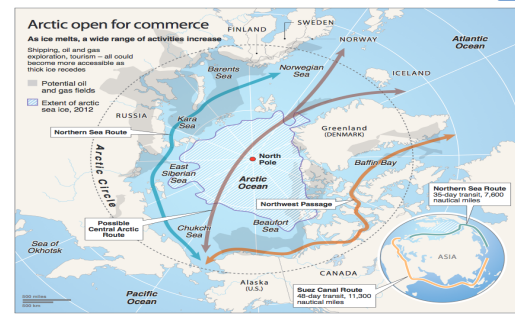
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Improved economy and more jobs



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Increased population



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Organic farming

Improved economy and more jobs

Increased population

Quality of life



What can we all do?

What can we all do?

Stay informed and inform others

What can we all do?

Stay informed and inform others

Energize legislators through contact and voting

What can we all do?

Stay informed and inform others

Energize legislators through contact and voting

Support climate-friendly activities

What can we all do?

Stay informed and inform others

Energize legislators through contact and voting

Support climate-friendly activities

Adopt climate-friendly solutions

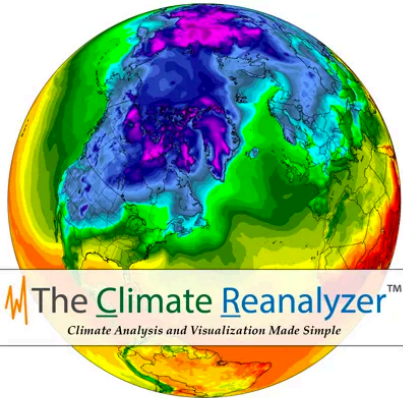
- increase efficiency

- reduce emissions

- reduce waste and reuse

*“The age of climate decision is here,
and our actions will define
the course of civilization
and the health of our planet.”*

Paul Andrew Mayewski



climatereanalyzer.org



10green.org