Climate Change in Maine

Precipitation Trends and Projections

Commission to Study the Role of Water
as a Resource for the State of Maine
6 October, 2022

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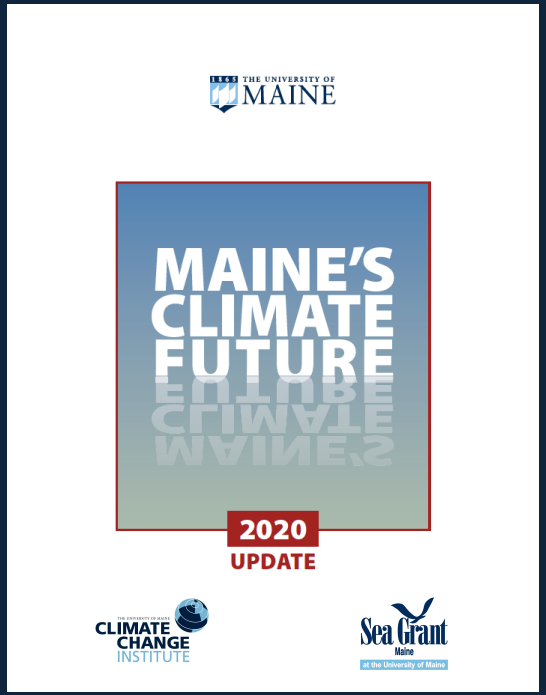
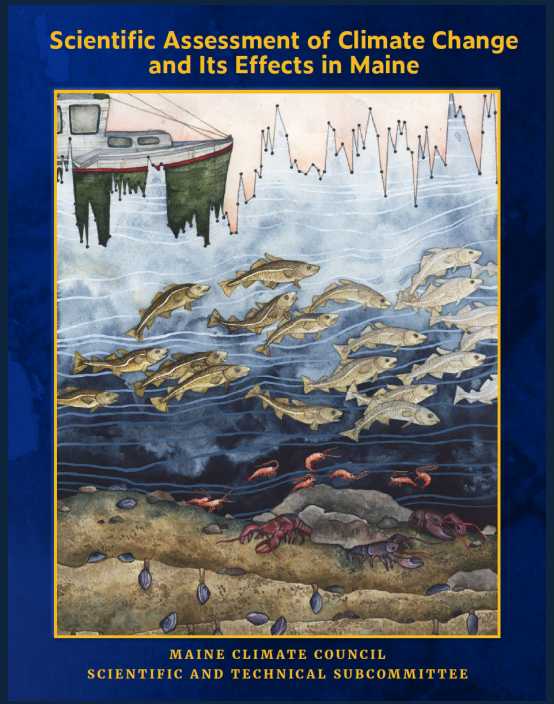
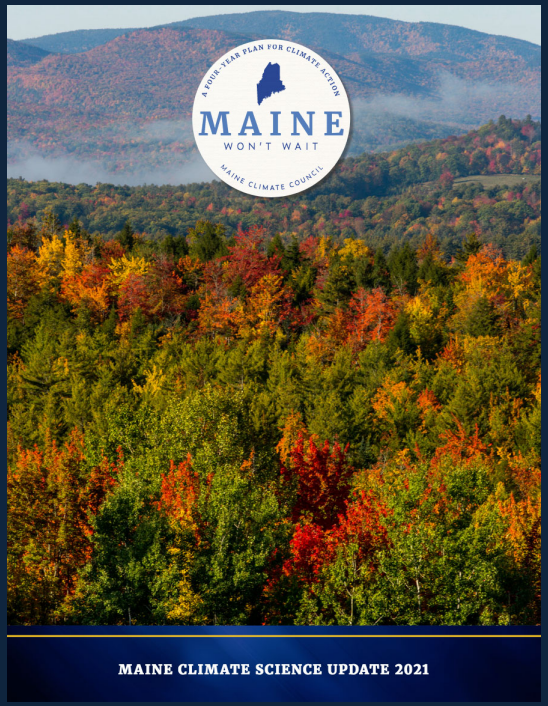
Presentation Outline

- Temperature and precipitation trends and projections
- Enhanced hydrologic cycle and extreme events
- Impacts from shorter snow season
- Drought overview


THE UNIVERSITY OF MAINE
MAINE'S CLIMATE FUTURE
2020
UPDATE
CLIMATE CHANGE INSTITUTE
Sea Grant Maine
at the University of Maine

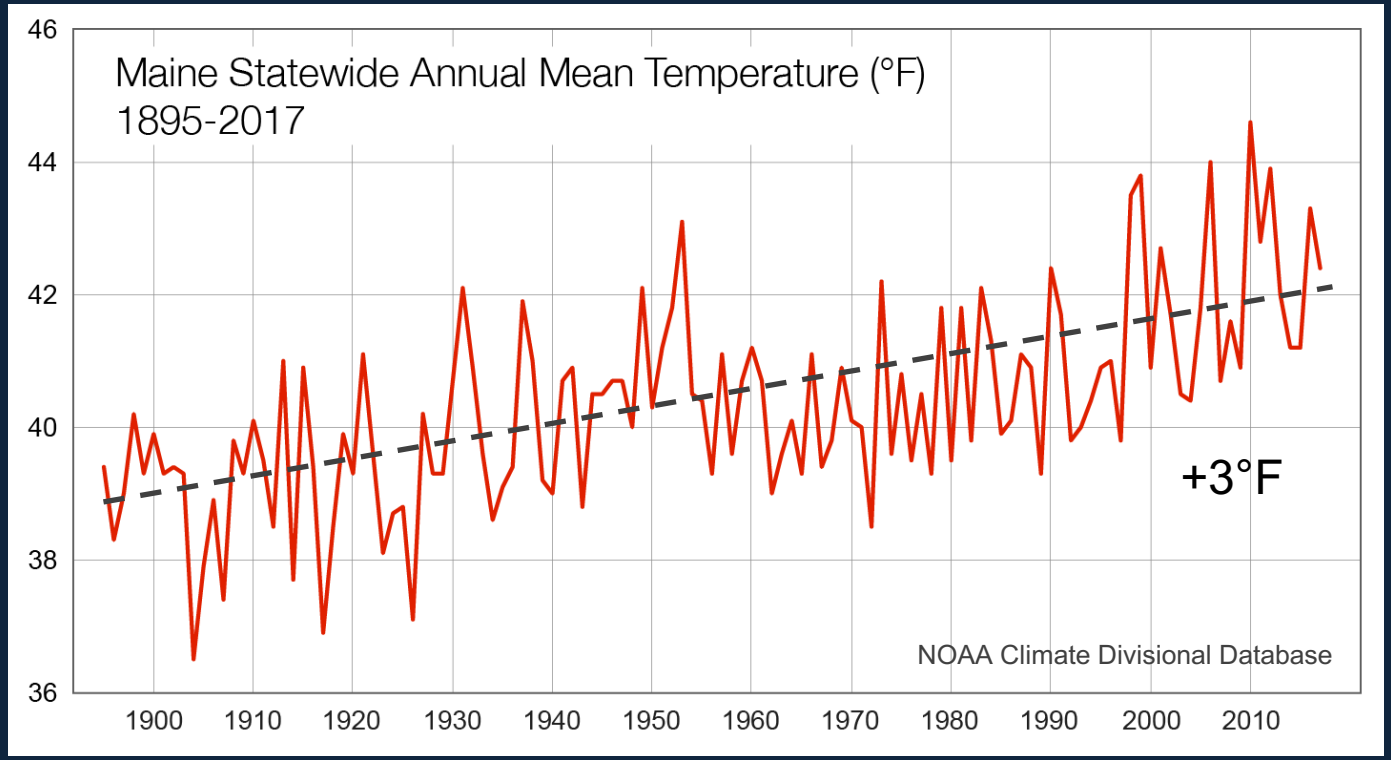

Scientific Assessment of Climate Change and Its Effects in Maine
MAINE CLIMATE COUNCIL
SCIENTIFIC AND TECHNICAL SUBCOMMITTEE


A FOUR-YEAR PLAN FOR CLIMATE ACTION
MAINE
WON'T WAIT
MAINE CLIMATE COUNCIL
MAINE CLIMATE SCIENCE UPDATE 2021

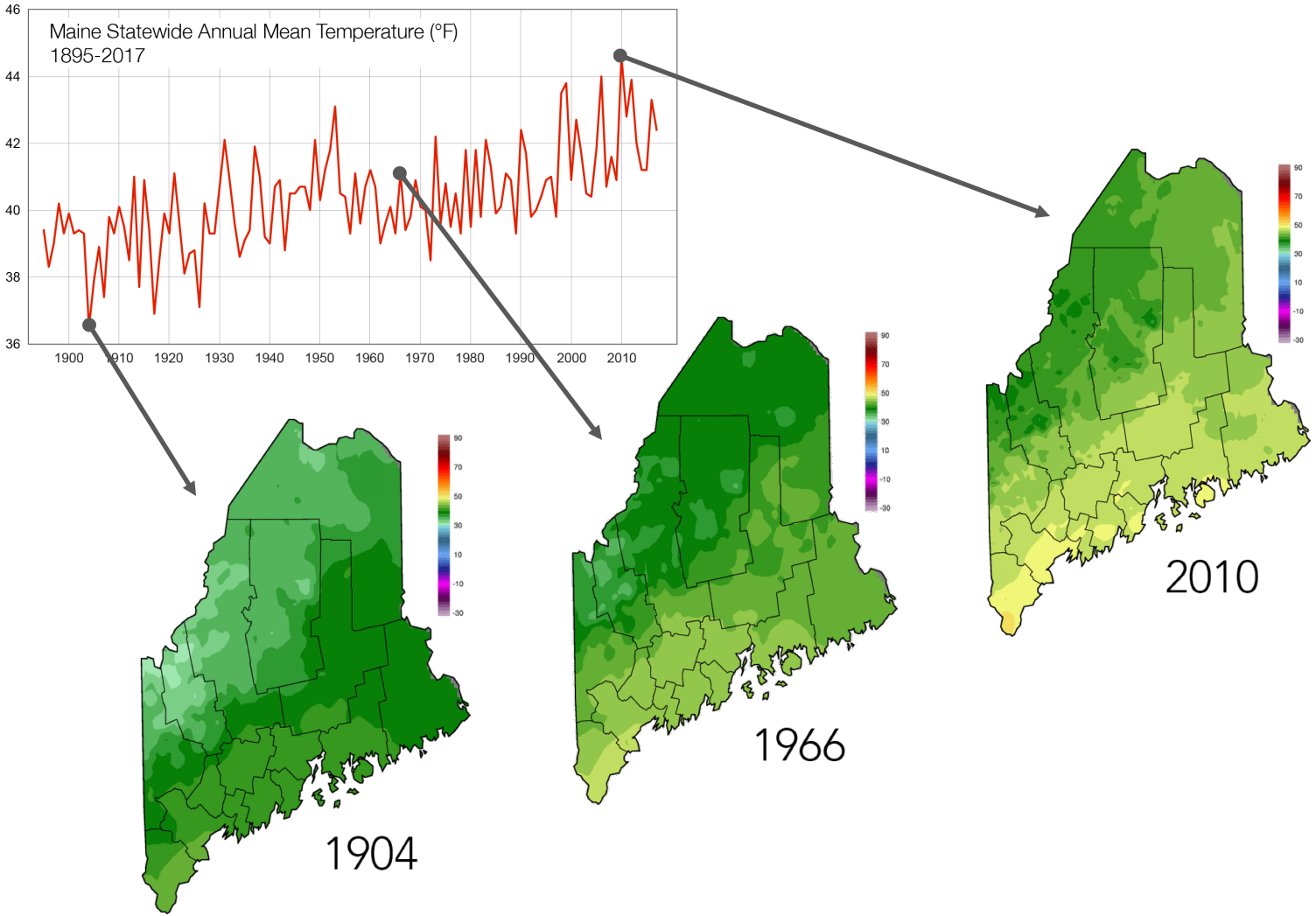
Key Points

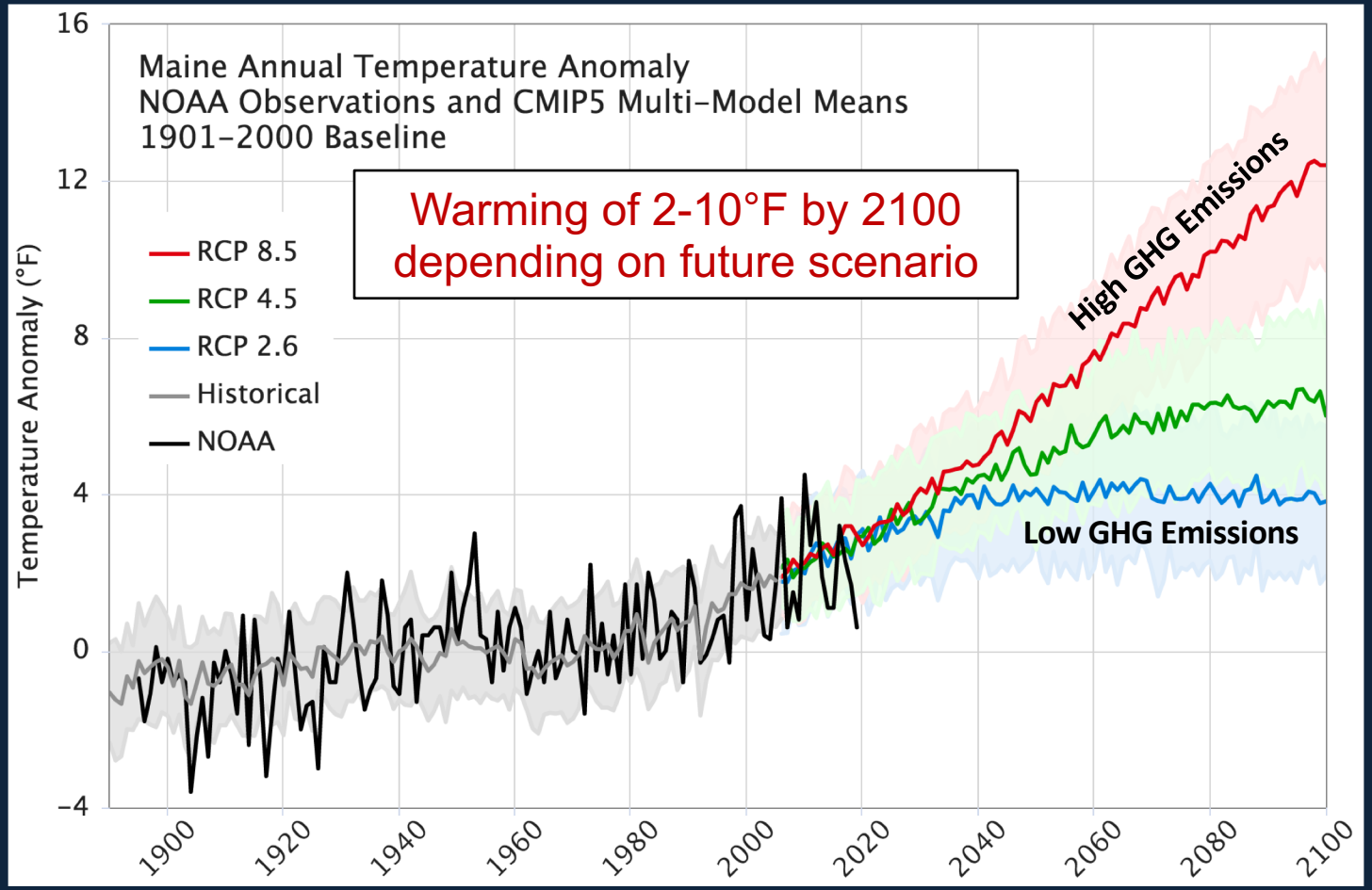
- Maine’s annual temperature has increased about 3°F since 1895; projected to warm is 2–4°F by 2050 and up to 10°F by 2100.
- Maine’s annual precipitation has increased about 6” since 1895; projected to increase 2–7” (5–14%) over this century.
- Increased heating intensifies the hydrologic cycle, producing more extremes, including heavy precipitation and enhanced drying from water evaporative loss.
- A shortening snow season is associated with earlier snowmelt and peak streamflows, which can lend to drier surface conditions in late spring.
- Meteorological drought has not increased over the past century. Short-term, intense dry periods are relatively common in the northeastern U.S.
- It is uncertain whether drought will become more or less common in the future. However, when variability does produce drought, warmer temperatures will likely exacerbate surface dryness through increased evaporative losses.

Temperature



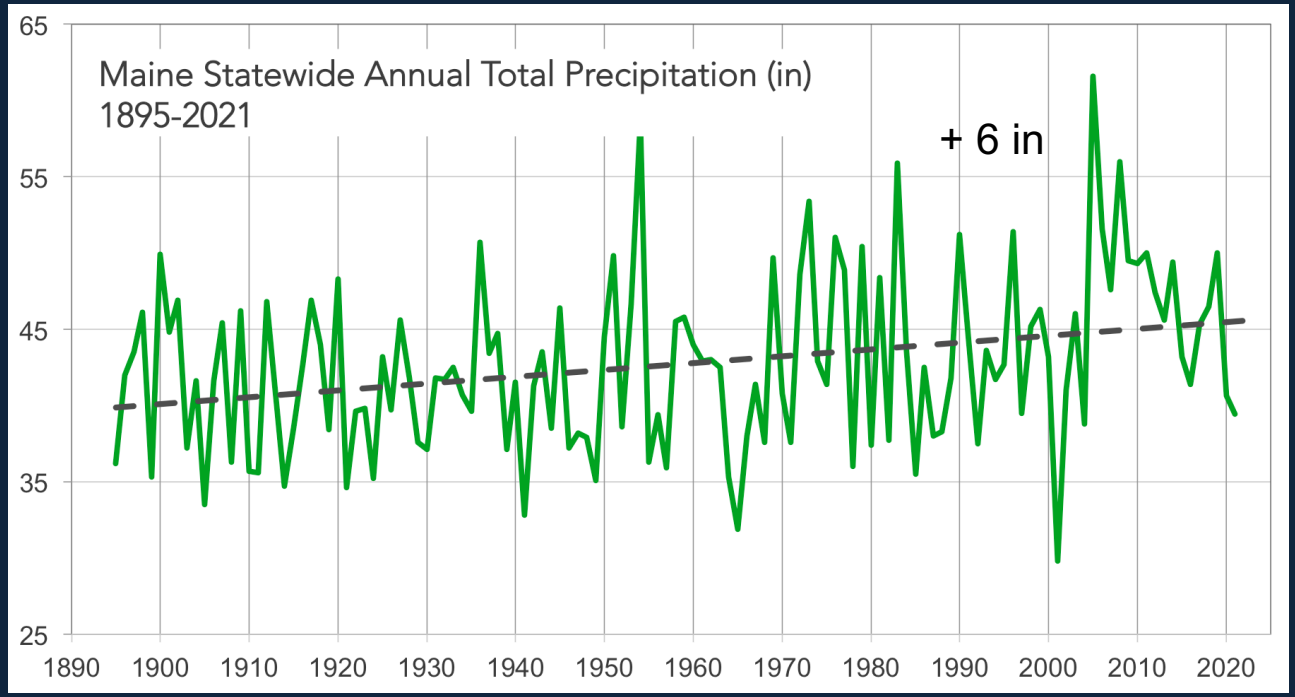
- Annual increase of 3°F since 1895
- Overnight lows have risen more than daytime highs
- The eight warmest years occurred since 1998


Maine Statewide Annual Mean Temperature (°F)
1895-2017
46
44
42
40
38
36
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
90
70
50
30
10
-10
-30
1904
1966
2010



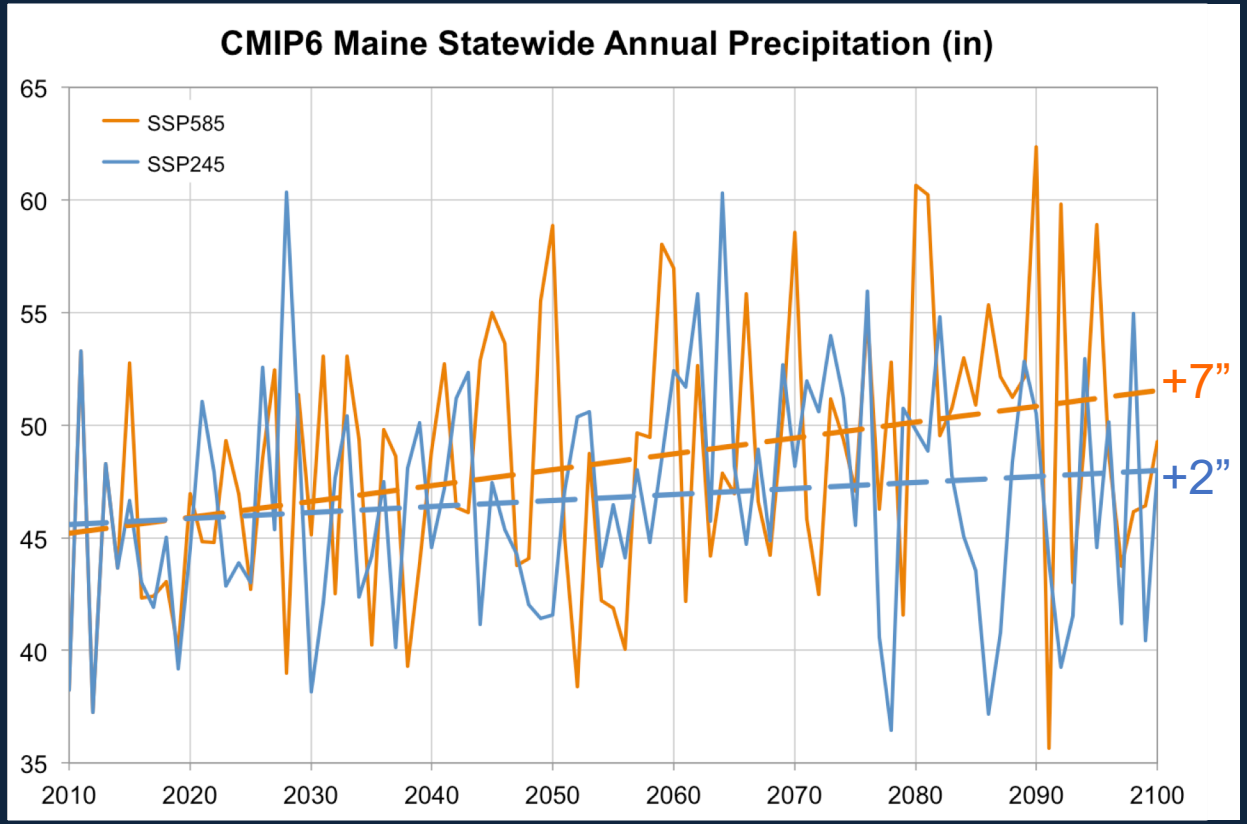
Maine's Climate Future 2020 Update
Maine Climate Council STS Report, 2020

Precipitation



NOAA Climate Divisional Database

- Maine's annual precipitation increased 6" since 1895. Largest increase last 20 years.
- Heavy precipitation events (> 2 in/day) have become more common.
- These trends are expected to continue.



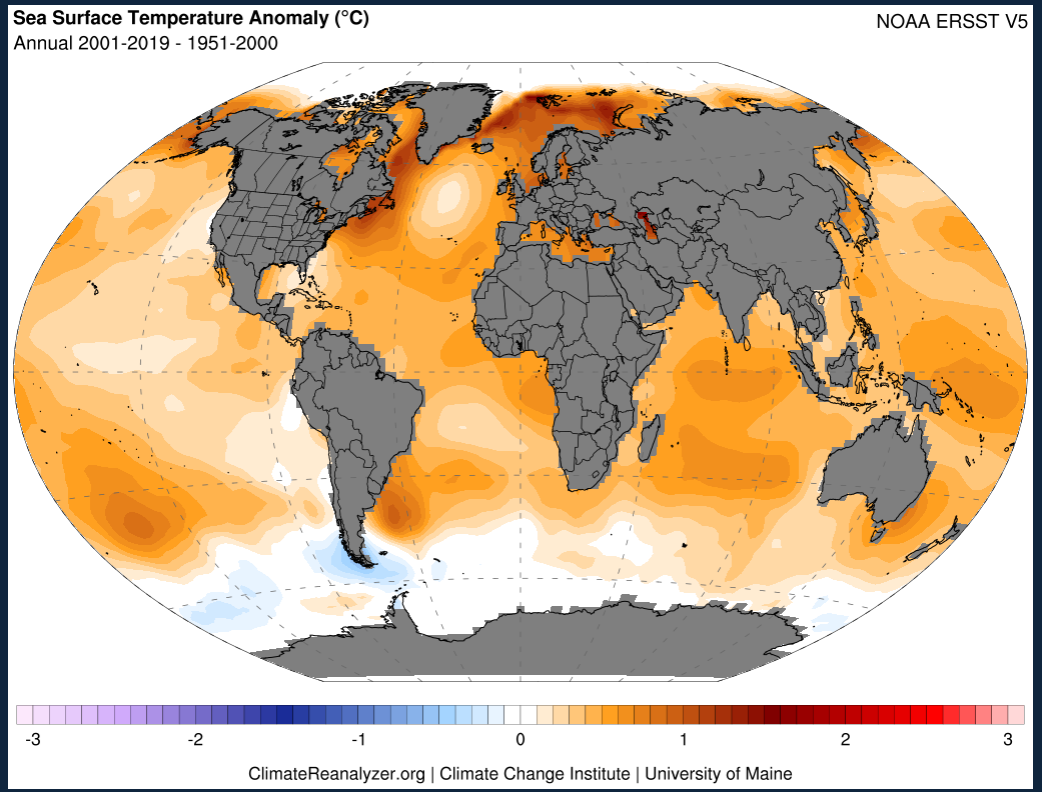
- CMIP6 projections suggest annual precipitation could increases 2–7” (5–14%) over this century.
- Future seasonal distribution of surpluses and deficits is uncertain.

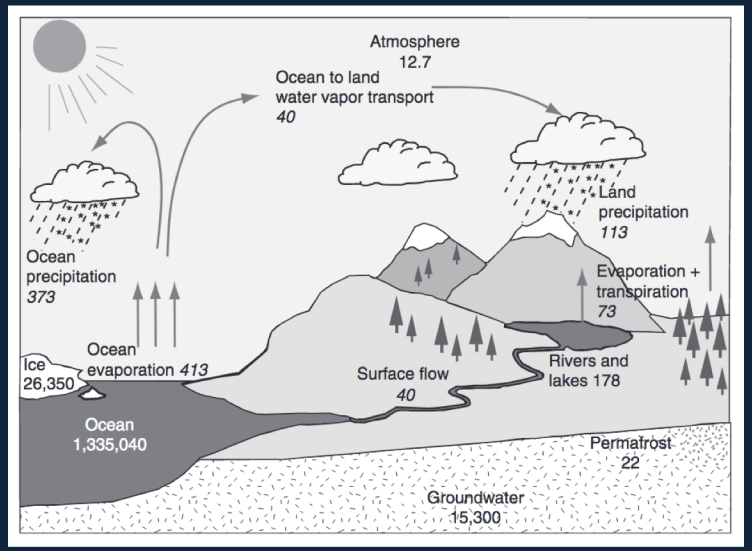
CMIP6 = Coupled Model Intercomparison Project version 6
SSP = Shared Socio-econmic Pathways

CMIP6 SSP 245, 585 are similar to CMIP5 RCP 4.5, 8.5

Ensemble average of 13 models (one member each: AWI-CM-1-1-MR, BCC-CSM2-MR, CAMS-CSM1-0, CanESM5 p1, CanESM5 p2, CESM2, CESM2-WACCM, FGOALS-g3, MCM-UA-1-0 f2, MIROC6, MIROC-ES2L f2, MRI-ESM2-0, UKESM1-0-LL f2). Gridded data downloaded from KNMI Climate Explorer; processed via UMaine Climate Reanalyzer.

Warming Oceans, Water Vapor Feedback, and Intensifying Hydrologic Cycle



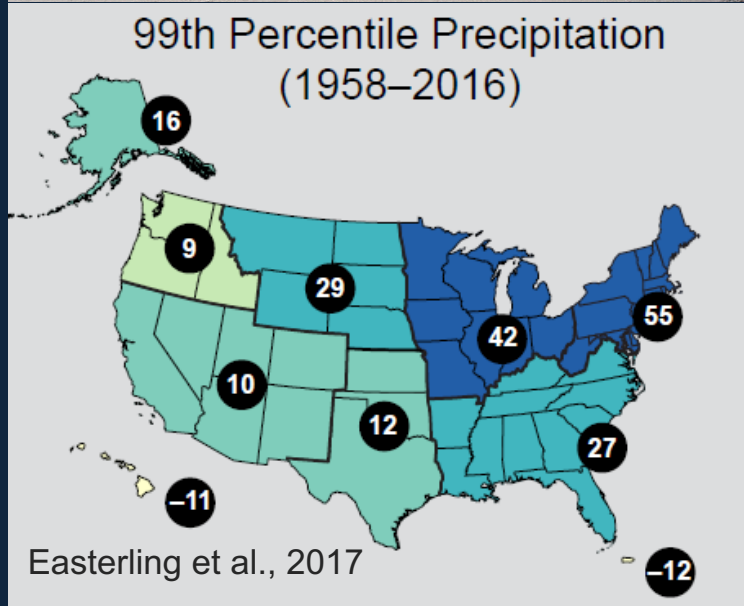


Trenberth et al. (2007), Huntington (2010)

- Warming drives increased evaporation, atmospheric water-vapor content, and potential for greater extremes (e.g., heavy precipitation, drought)

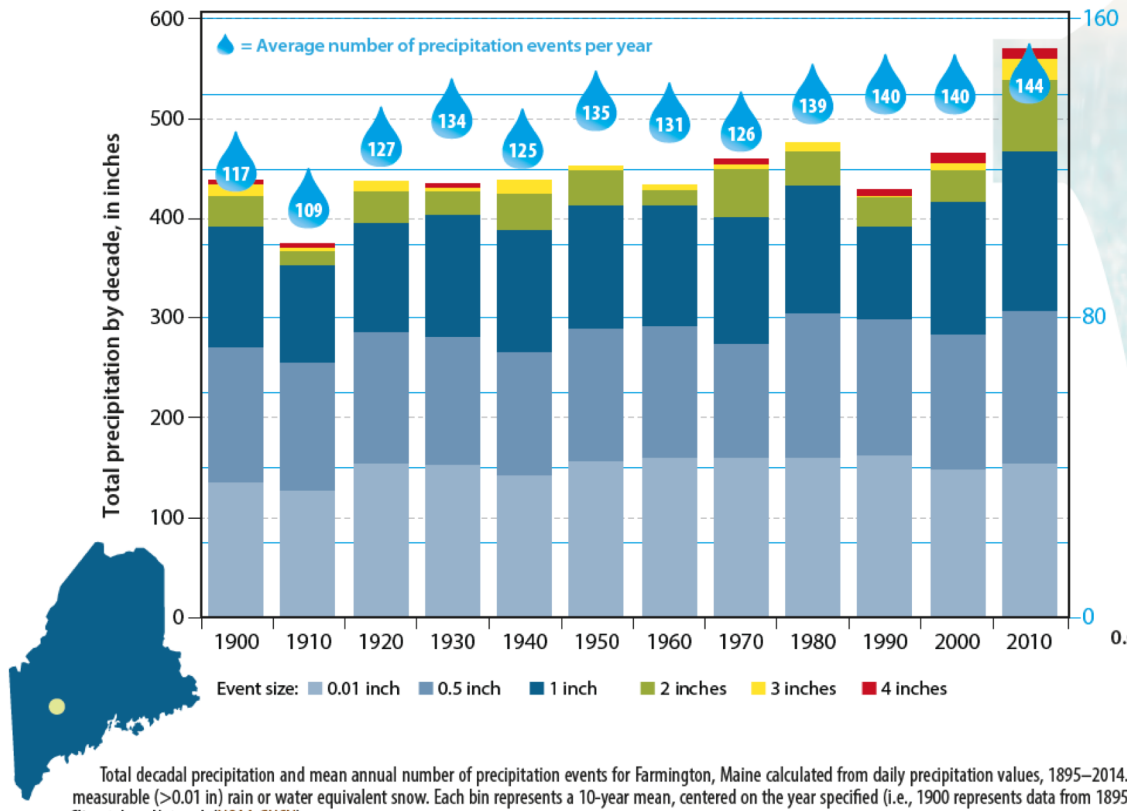
Extreme Weather

- Extreme weather is becoming more common around the N. Hemisphere due to changes in atmospheric circulation.
- Increased likelihood of heat/cold waves, intense storms.
- Large increases (55%) in annual heavy daily precipitation across the USNE.
- In Maine, the last 10-15 years have seen the highest occurrence of 2”, 3”, and 4” precipitation events (Fernandez et al., 2020).

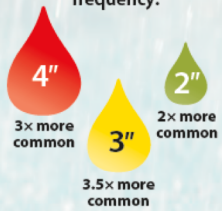


Easterling et al., 2017

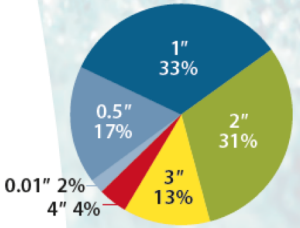
Precipitation at Farmington, Maine



We are experiencing heavier rains. While still relatively uncommon, events of 2, 3, or 4 inches have increased in frequency.

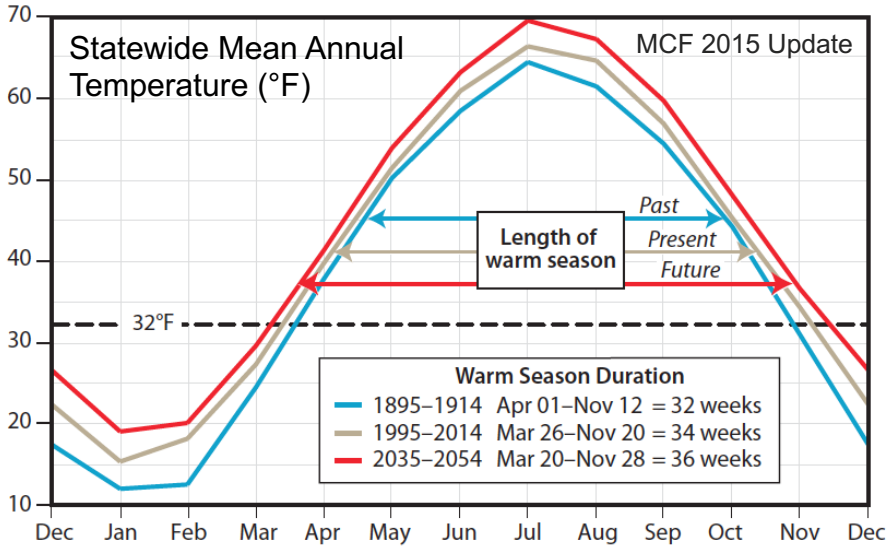


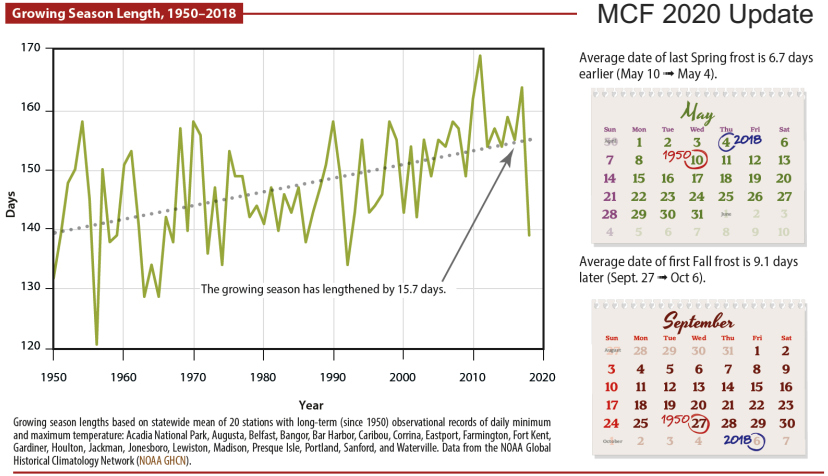
…However, the 30% increase (13 inches per year) in average precipitation for 2005–2014 compared to previous decades was mostly due to more 1-inch and 2-inch events:



Percent increase in precipitation events

Total decadal precipitation and mean annual number of precipitation events for Farmington, Maine calculated from daily precipitation values, 1895–2014. Precipitation events are defined as days with measurable (>0.01 in) rain or water equivalent snow. Each bin represents a 10-year mean, centered on the year specified (i.e., 1900 represents data from 1895–1904). Data from the NOAA Global Historical Climatology Network (NOAA GHCN).





Season Lengths are Changing

- The warm season has increased and snow season has decreased by about 2 weeks over the past century.
- Since 1950, the growing season has lengthened by ~16 days (Fernandez, 2020).
- Summer weather and growing season extension mostly into fall.
- Trends projected to continue, but some years will bring unexpected late spring or early fall frosts.

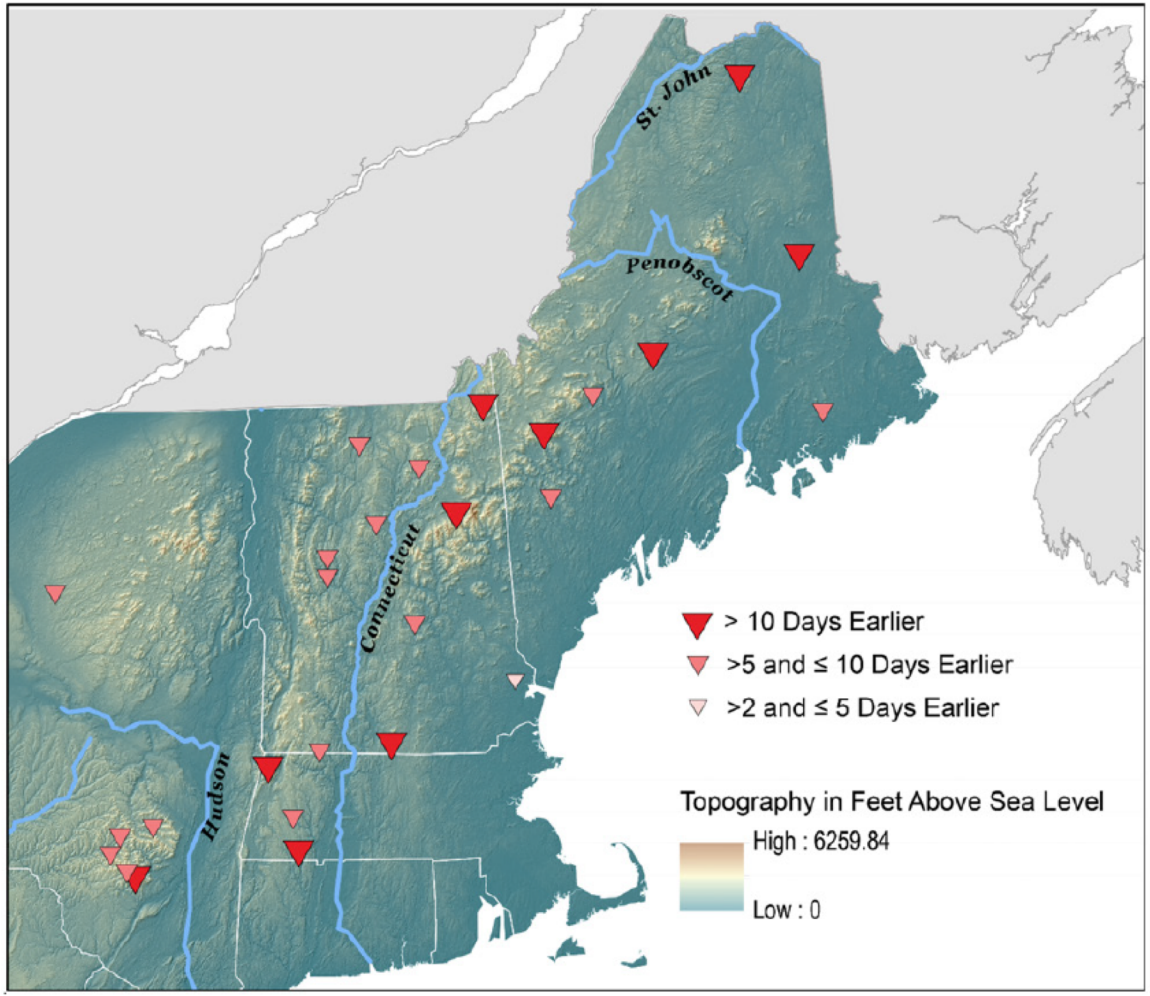


Figure 1. Map depicting historical changes in the timing of snowmelt-related streamflow for sites across the northeastern U.S. from 1960 to 2014 [Figure from Dupigny-Giroux et al., 2018, based on Dudley et al., 2017].

Snowmelt & Streamflow

- Trend toward earlier winter-spring melt runoff
  - 7–14 days earlier than ~ 1950
  - Related to small increases in February–May air temps
- Trends projected to continue, e.g., Hayhoe et al. (2007), Demaria et al. (2016)

Maine Climate Council STS Report, 2020

Drought Overview

General Categories

Meteorological (precipitation)

Agricultural (soil moisture)

Hydrologic (runoff, streamflow, and groundwater)

Drought Indices

Palmer Drought Severity Index (PDSI)

Standardized Precipitation Index (SPI)

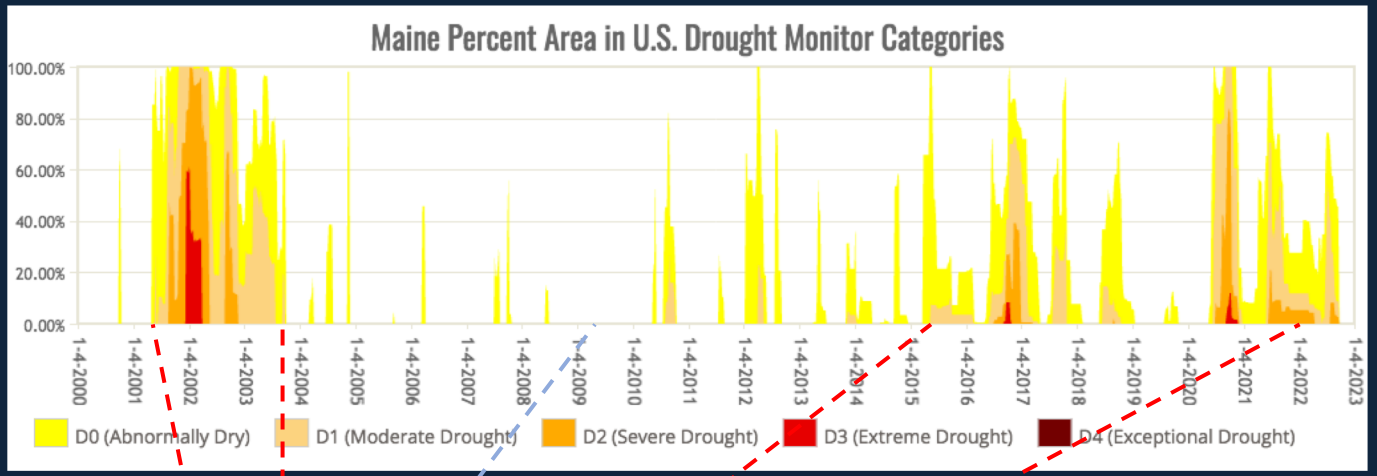
SPEI = SPI + evapotranspiration

Short-term or "flash" droughts (2-6 months), followed by quick return to normal or above normal precipitation, are common in the USNE.

U.S. Drought Index Descriptions

Category	Description	Possible Impacts	Palmer Drought Index	CPC Soil Moisture (Percentiles)	USGS Weekly Streamflow (Percentiles)
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9	21-30	21-30
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9	11-20	11-20
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed	-3.0 to -3.9	6-10	6-10
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions	-4.0 to -4.9	3-5	3-5
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0-2	0-2

National Weather Service & U.S. Drought Monitor
https://www.weather.gov/riw/drought_index
https://droughtmonitor.unl.edu/



U.S. Drought Monitor
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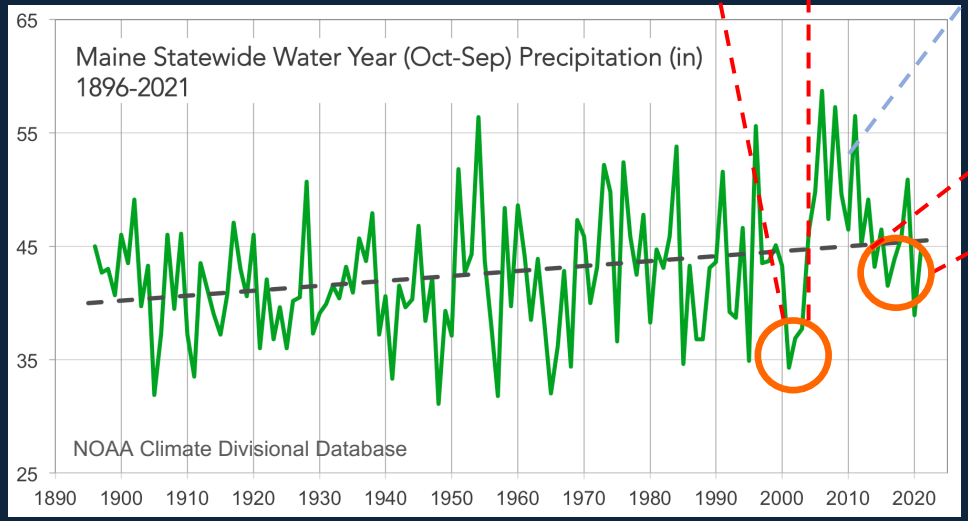


USGS
science for a changing world

Lombard et al., 2020

2020 Drought in New England

Below average and infrequent rainfall from May through September 2020 led to an extreme hydrologic drought across much of New England, with some areas experiencing a flash drought, reflecting its quick onset. The U.S. Geological Survey (USGS) recorded record-low streamflow and groundwater levels throughout the region. In September, the U.S. Department of Agriculture (2020) declared Aroostook County in Maine and Hillsborough and Merrimack Counties in New Hampshire as crop disaster areas. By the beginning of October, 166 community water systems and 5 municipalities in New Hampshire, more than 100 municipalities in Massachusetts, and several community water supplies in Connecticut, Maine, and Rhode Island had mandatory water restrictions in place (Northeast Regional Climate Center, 2020b).

Photograph of a dry stream channel at Mill River at Cook Hill Road near Cheshire, Connecticut, at U.S. Geological Survey streamgage 01196588 on September 3, 2020; photograph by Narcyz Dubicki, USGS.

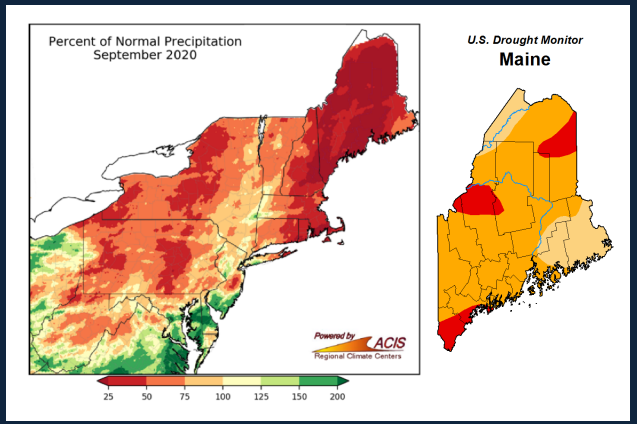
Highlights

- Much of the scarce precipitation during summer 2020 fell in a few storms, leaving long periods with little to no rain.
- Northern and central Maine were in a flash drought by the beginning of July; southeastern Massachusetts, northern Rhode Island, and northeastern Connecticut, by the beginning of August.
- During September, 14 USGS streamgages recorded the lowest 7-day average streamflows in the past 30 years; the USGS recorded the lowest streamflow measurements in the past 30 years at 14 streamgages.
- The lowest monthly groundwater levels in the past 25 years were recorded at 24 USGS monitoring wells during the summer.

Photograph of Kingsbury Stream at Abbot Village, Maine, from U.S. Geological Survey streamgage 01031450 on September 29, 2020; photograph by Andrew Cloutier, USGS.

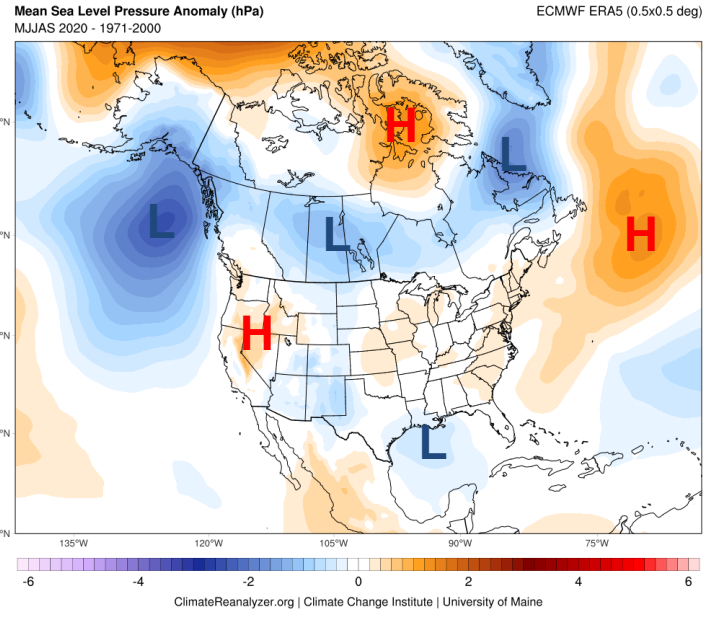
2020/21 Drought

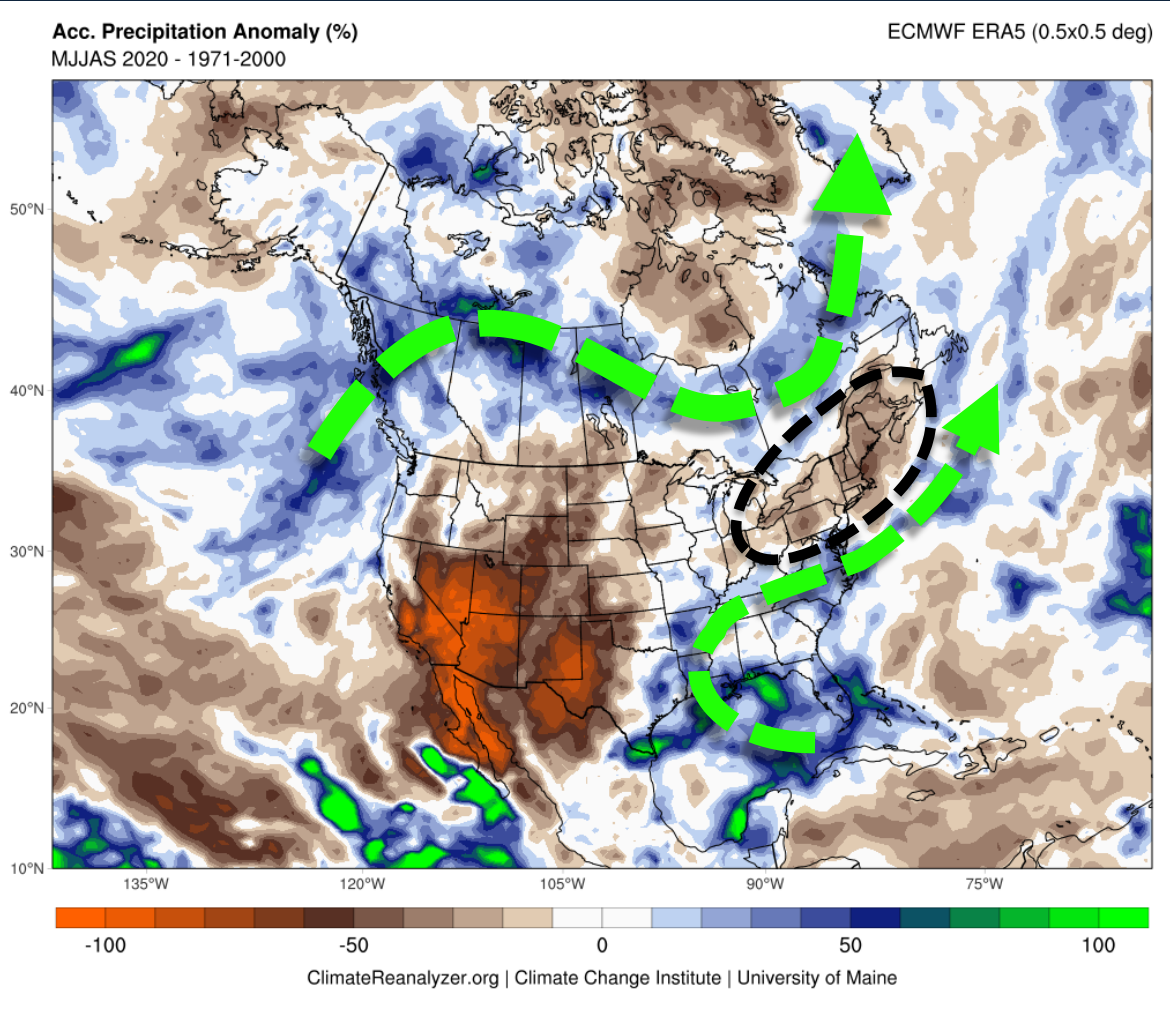
- After a cool spring with late snowfall and good snowpack, dryness set in quickly middle of May. Drought conditions developed and persisted for several months with significant impact to water resources and agriculture.
- September, ranked as the driest month on record, saw the most severe conditions and drought disaster declarations made by the U.S. Secretary of Agriculture.
- During September the Piscataquis, Saint John, and Aroostook Rivers had record low flows and significant riverbed exposure.
- Beneficial rains in October and November brought conditions to near-norm.
- Drought signal carried into 2021 due to warm winter with below normal snowfall, and early spring snowmelt.

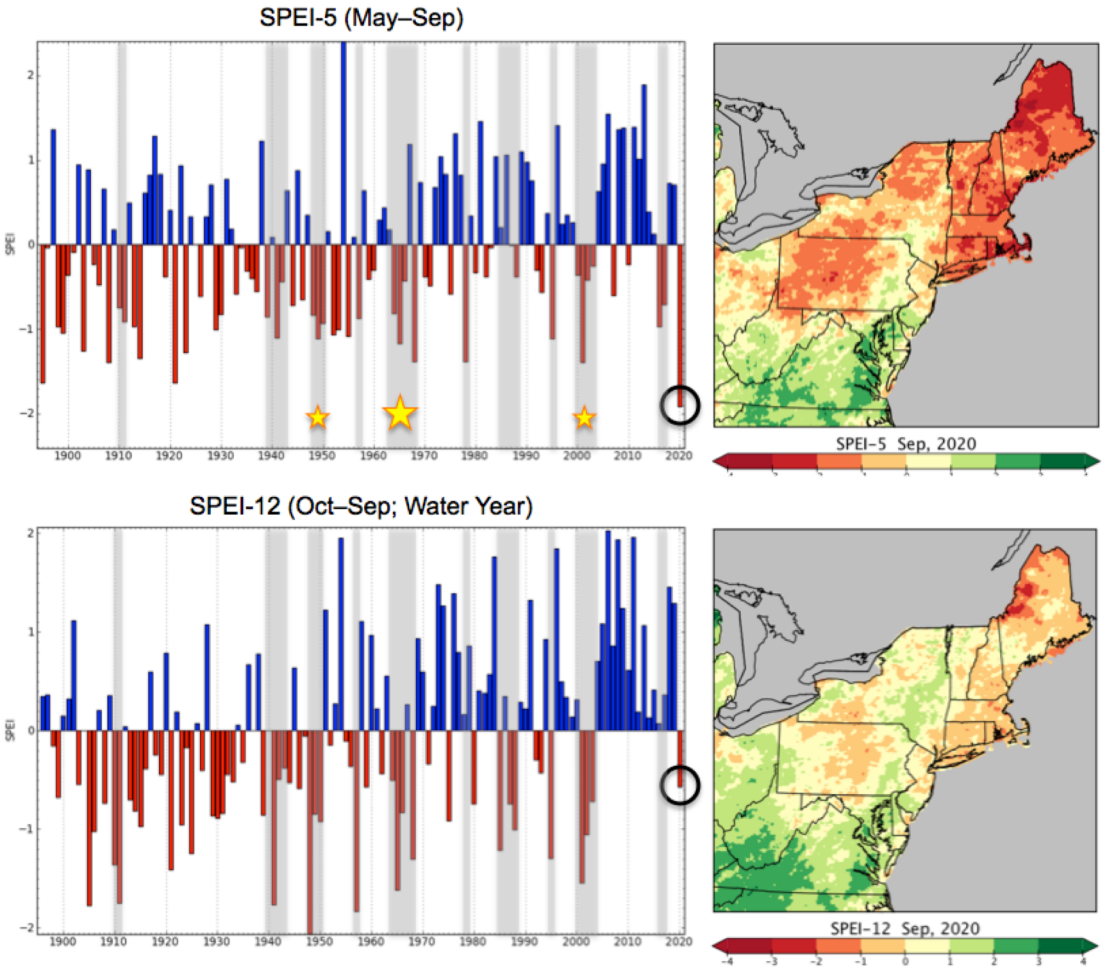


D0 (abnormal dryness)
D1 (moderate drought)
D2 (severe)
D3 (extreme)

2020 May–June Weather Patterns



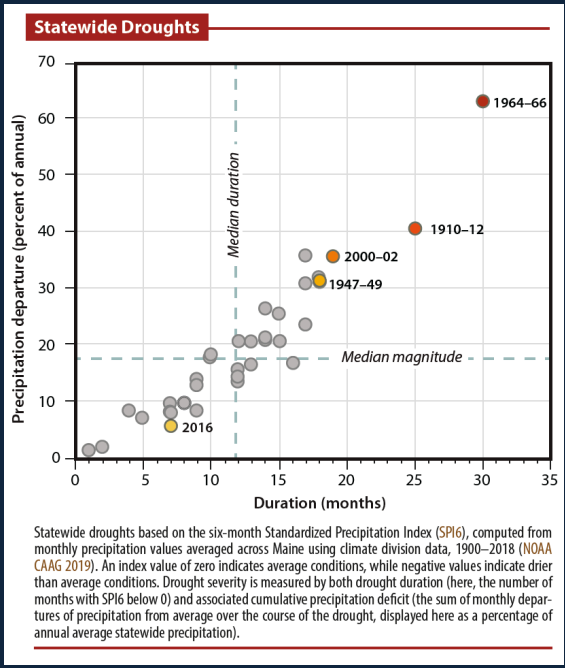




SPEI = Standardized Precipitation-Evapotranspiration Index
Gray shading = known droughts (e.g., Lombard, 2004; MCF 2020 Update)

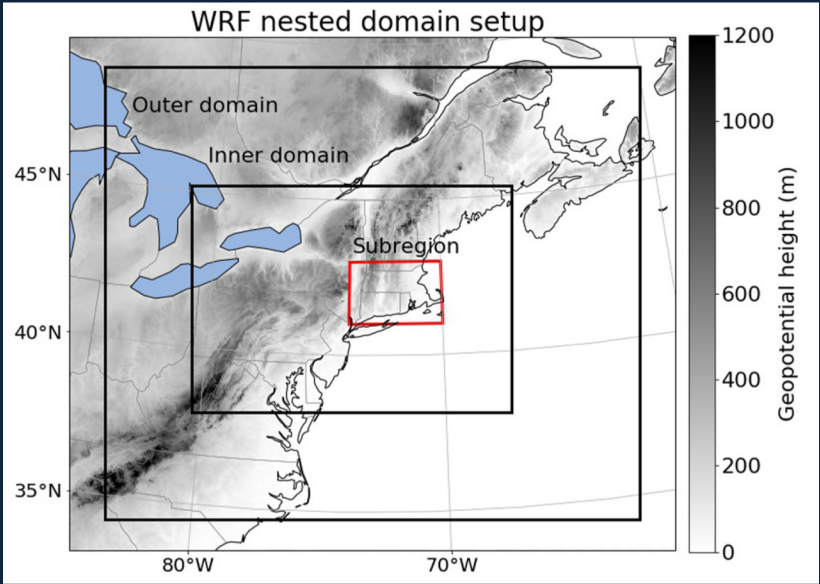
Data from Western Region Climate Center
https://wrcc.dri.edu/wwdt/time/

- Meteorological drought has not increased over the past century.
- Uncertain whether drought will become more or less common in the future.
- However, when droughts develop, warmer temperatures will likely exacerbate dryness through increased evaporative losses.



Statewide droughts based on the six-month Standardized Precipitation Index (SPI6), computed from monthly precipitation values averaged across Maine using climate division data, 1900–2018 (NOAA CAAG 2019). An index value of zero indicates average conditions, while negative values indicate drier than average conditions. Drought severity is measured by both drought duration (here, the number of months with SPI6 below 0) and associated cumulative precipitation deficit (the sum of monthly departures of precipitation from average over the course of the drought, displayed here as a percentage of annual average statewide precipitation).

A Retrospective and Prospective Examination of the 1960s U.S. Northeast Drought



Xue and Ullrich (2021)

- The 1962–1966 drought remains the drought of record.
- Used mesoscale model to test hydroclimate outcomes for the 1960s drought under future warming.
- Applied temperature delta (all levels) to ECMWF CERA-20C historical forcing for period 1961–1967 (first year used as spin up).
- Future temps based on multi-model ensemble averages of CMIP6 high-emissions (SSP585) for 2021–2027, 2041–2047, and 2091–2097.
- Warming produces increased precipitation and soil moisture, but also increased evapotranspiration and reduced snowpack.
- Increased extremes with wet months becoming wetter and dry months becoming drier.
- Increasingly rapid transitions from wet to dry, posing water management challenges.
- Trend towards wetter conditions likely to provide little relief from the effects of extremely dry months.
- Additional impacts include more extreme hot days, reduced snowpack, diminished frozen ground, and less surface runoff.

Key Points

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- It is uncertain whether drought will become more or less common in the future. However, when variability does produce drought, warmer temperatures will likely exacerbate surface dryness through increased evaporative losses.

Questions?

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