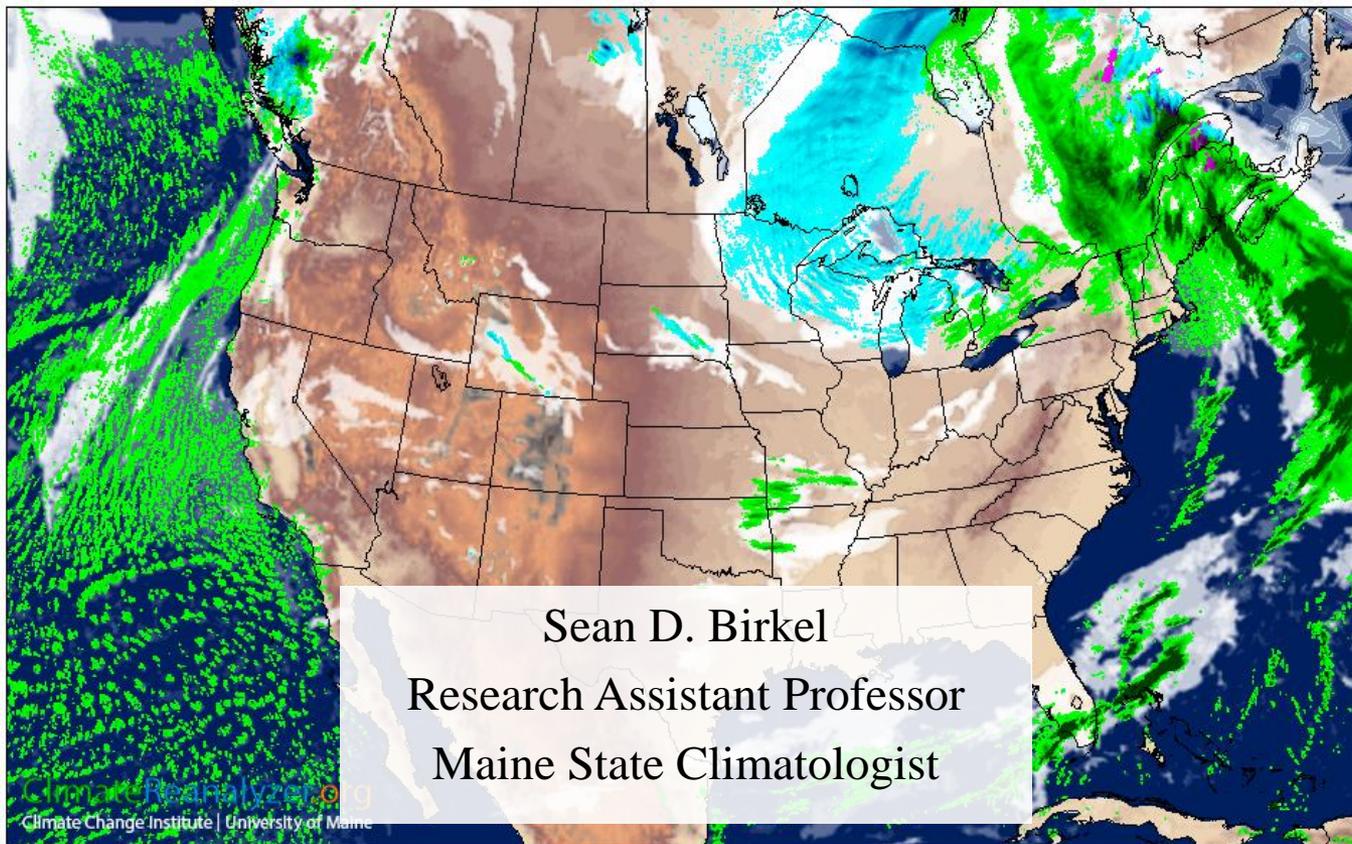


Maine's Recent and Future Climate

Precipitation/Clouds/Pressure
NCEP HIRES CONUS (5 km)

Forecast Valid - Tue 1300 EDT, Apr 21, 2015
017h from Mon 2000 EDT, Apr 20, 2015



Maine Emergency Preparedness Conference

Augusta Civic Center

April 21st, 2015

Talk Outline

- UMaine/CCI Software Tools
- Recent Weather Extremes
- Historical Context
- What might we see in the coming decades?

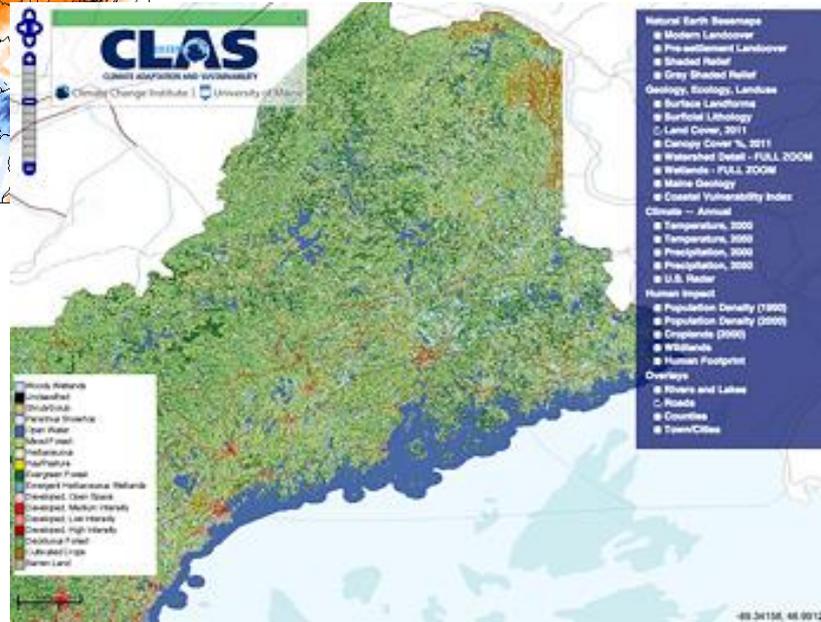
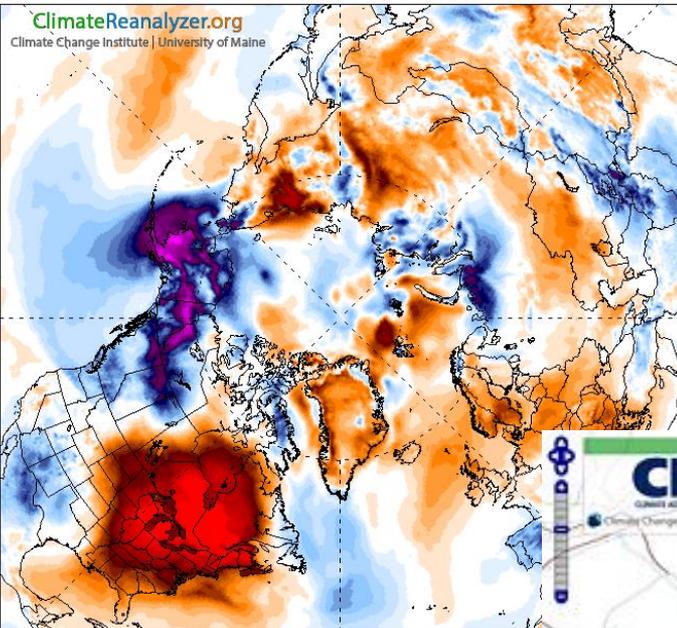


WHAT'S YOUR SCORE?

- 5
Houston
- 4
New York
- 3
Los Angeles
- 4
Chicago

Climate Reanalyzer | cci-reanalyzer.org

How healthy is your environment?



cci-reanalyzer.org/CLAS_Layers

10Green - Score History for Augusta, ME
10green.org/history.html

10GREEN THE UNIVERSITY OF MAINE

About The Score Standards Climate Reanalyzer CCI

Score History for Augusta, ME

The Score > Augusta, ME > History

If the 10Green score increases toward the present, then the environment is getting healthier and/or sampling has improved.

5
Augusta, ME

- > Score Summary
- > Score Over Time
- > Compare Scores
- > Health Implications
- > Change Location

Enter another ZIP or City, State to compare

Honolulu, HI

GET IT ON Google play

Healthy Measures (The 10Green Score)

Year	Score
1980	0
1984	3
1989	2
1993	3
1997	5
2001	5
2006	6
2010	6
2014	5

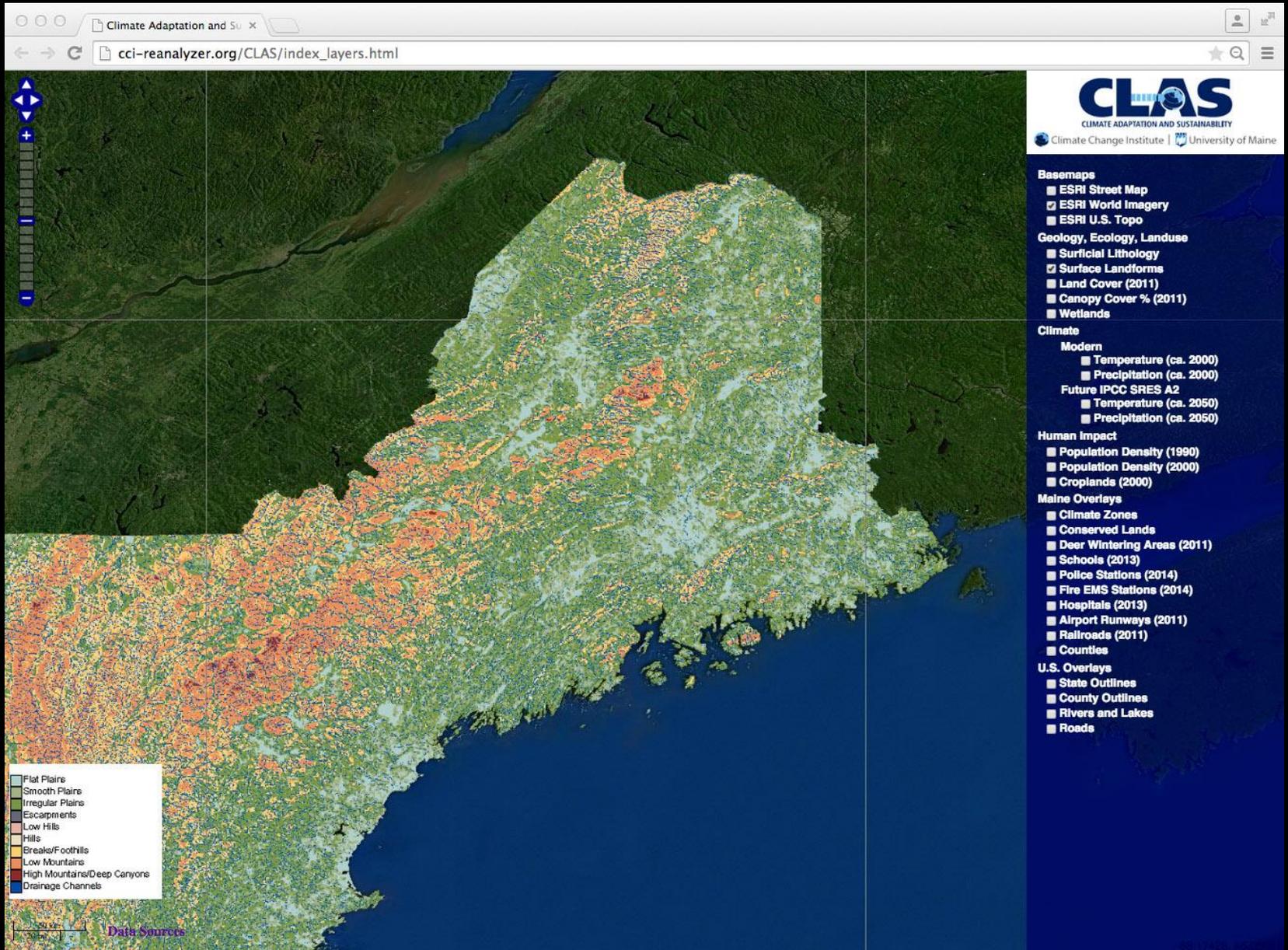
Unhealthy Measures

Year	Score
1980	2
1984	4
1989	4
1993	5
1997	3
2001	4
2006	5
2010	4
2014	4

Measures with No Data

Year	Score
1980	8
1984	4
1989	4
1993	2
1997	2
2001	1
2014	1

THE UNIVERSITY OF MAINE
CLIMATE CHANGE INSTITUTE
An initiative of the Climate Change Institute at the University of Maine.



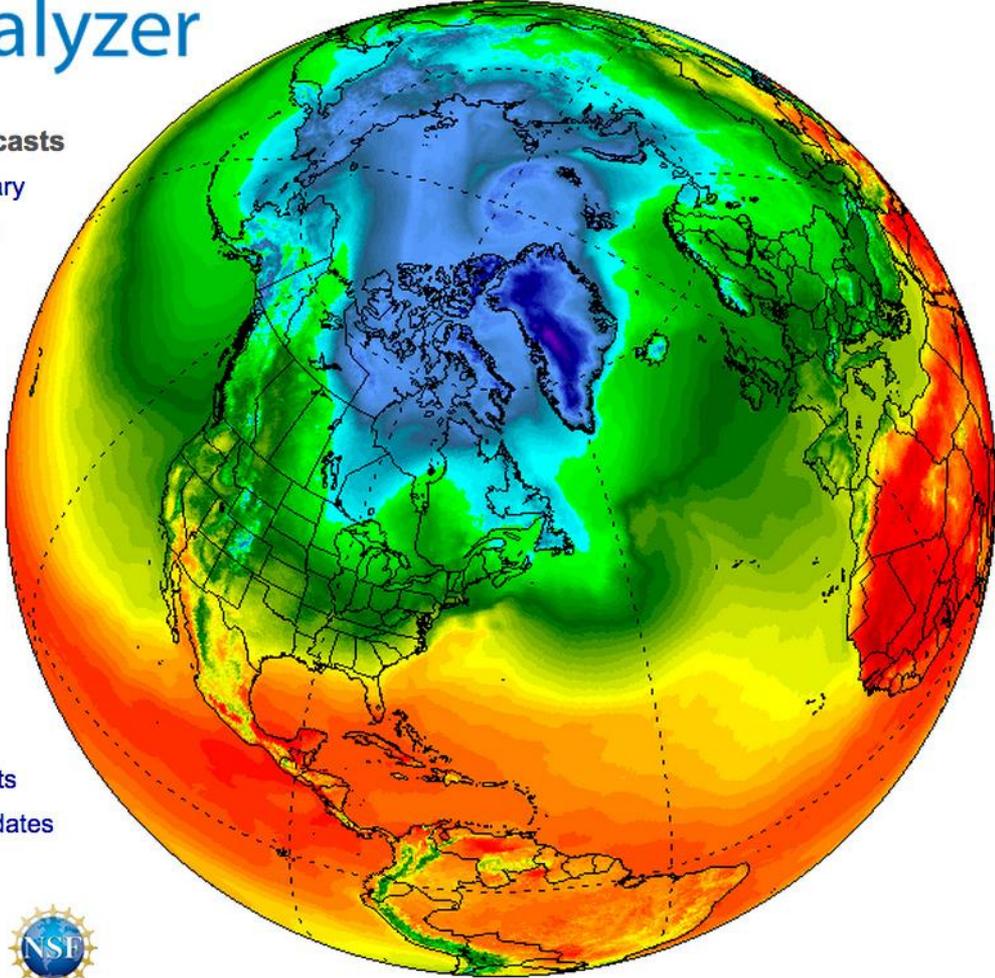
Climate Layers

<http://cci-reanalyzer.org/CLAS>

Climate Reanalyzer
cci-reanalyzer.org

Climate Reanalyzer

- Weather Forecasts**
 - Today's Summary
 - Forecast Maps (2 and 7-day)
- Climate Models and Data**
 - Daily Reanalysis Maps
 - Monthly Reanalysis Maps
 - Monthly Reanalysis Timeseries
 - Monthly Reanalysis Correlations
 - Monthly U.S. PRISM Maps
 - Daily GHCN Station Data
 - Environmental Change Model
 - Animation Gallery
- About Climate Reanalyzer**
 - Overview
 - Available Datasets
 - News and Updates



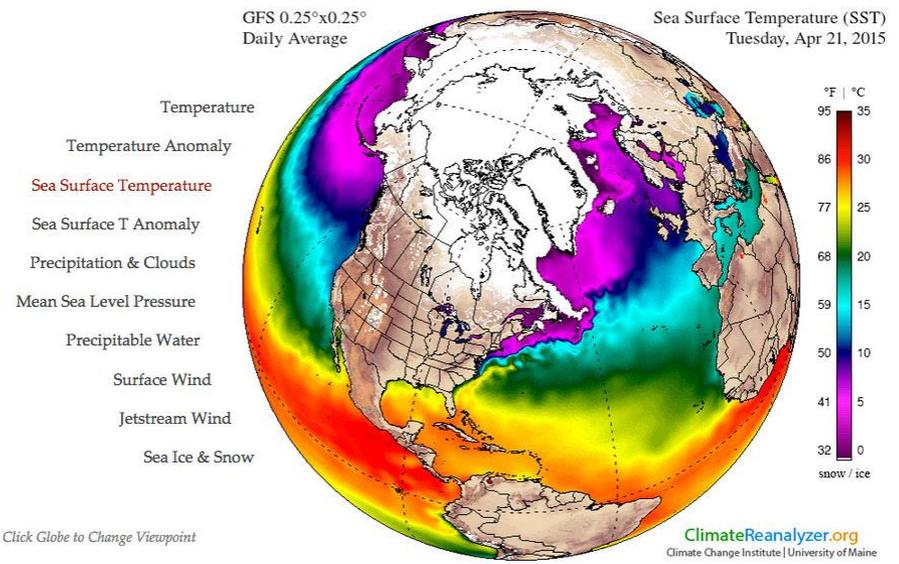
CLIMATE CHANGE INSTITUTE
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1865 THE UNIVERSITY OF MAINE

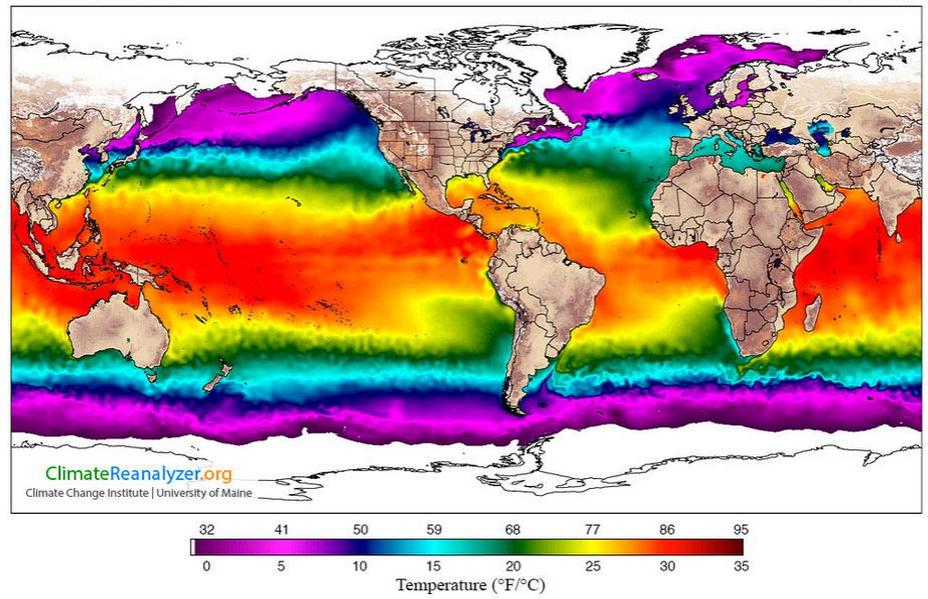
NSF

Climate Reanalyzer
<http://cci-reanalyzer.org>

Today's Weather Summary



Sea Surface Temperature (SST)
NCEP GFS (0.25°x0.25°) Tuesday, Apr 21, 2015
Daily Average

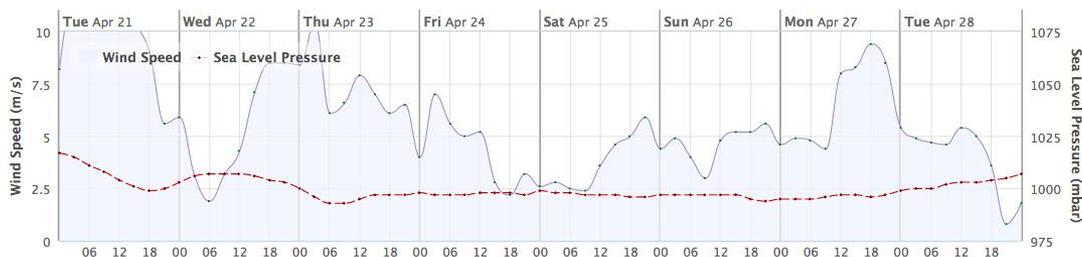
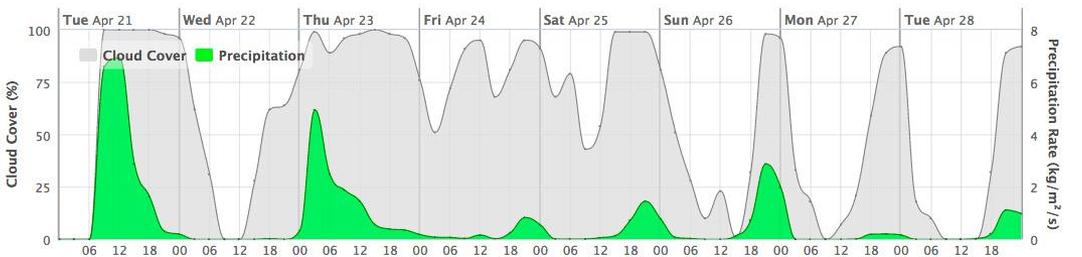
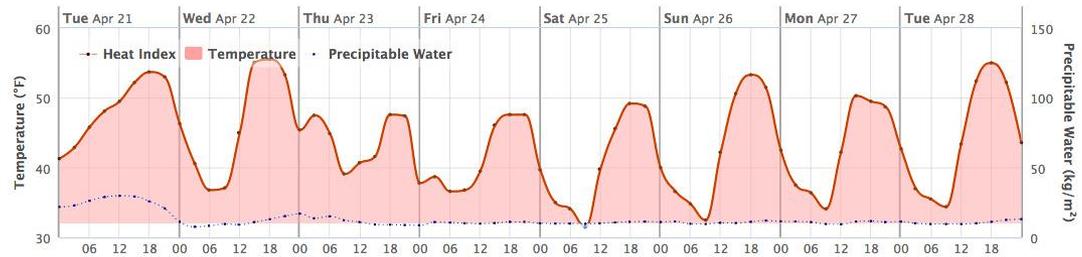


Your Weather Search

Current 8-day Weather Forecast

NCEP Global Forecast System (GFS) 0.25°x0.25°

Augusta, ME (44.3°N, 69.8°W)



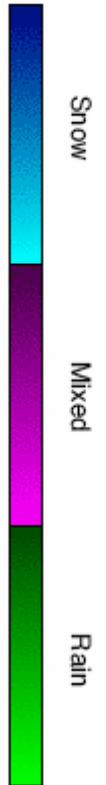
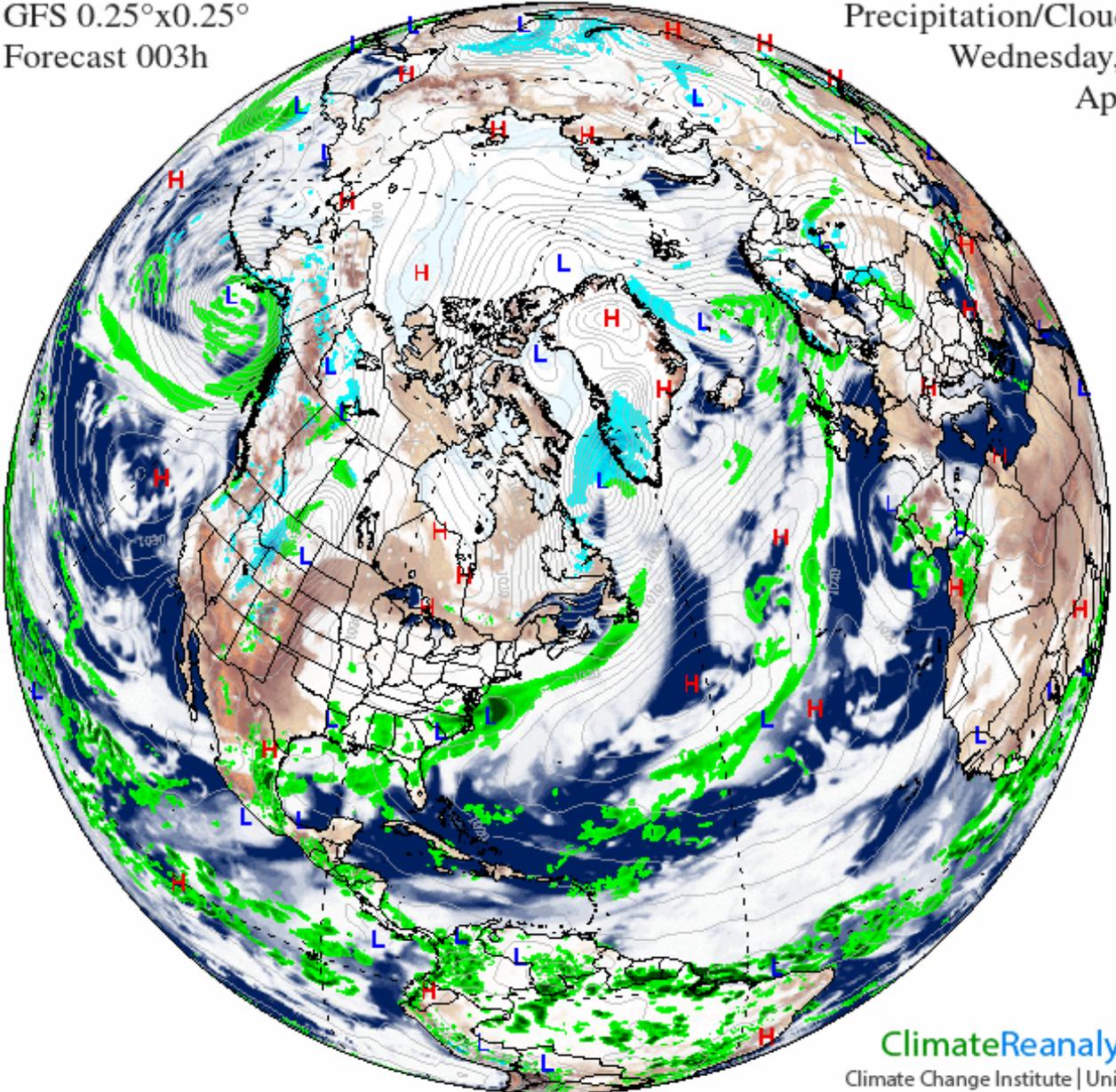
Location Map

[Download Text File](#)



GFS 0.25°x0.25°
Forecast 003h

Precipitation/Clouds/Pressure
Wednesday, 0300 UTC
April 15, 2015



Environmental Change Model

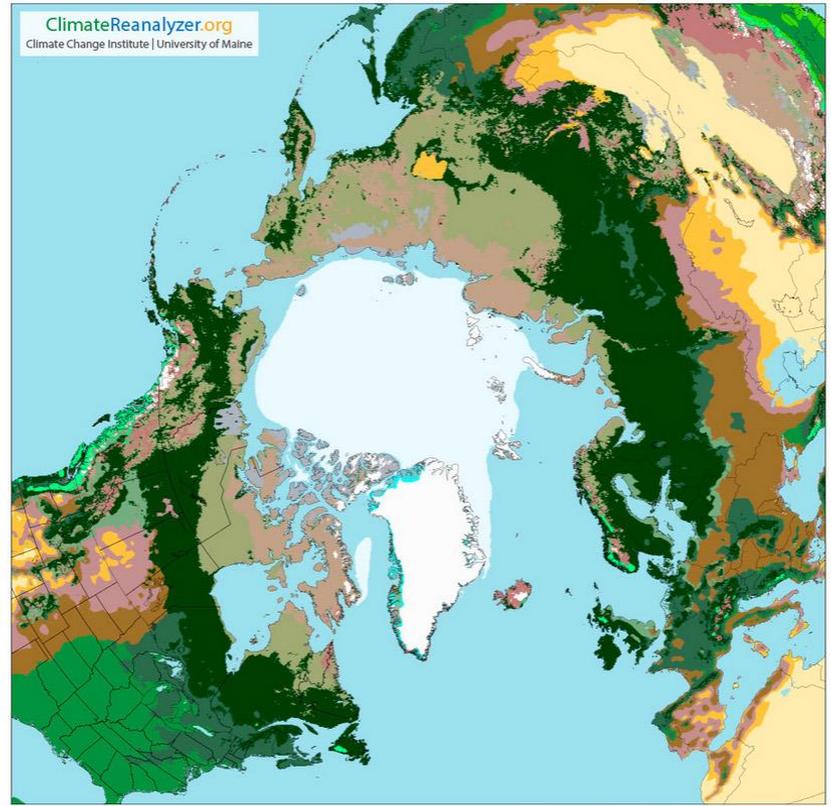
[What is the ECM?](#)

Region: Parameter: Month:

Global ΔT °C:

Playback:

Global $\Delta T = 0^\circ\text{C}$ Modern Climate, 1979-2000 Equilibrium



Environmental Change Model, Version 2015A

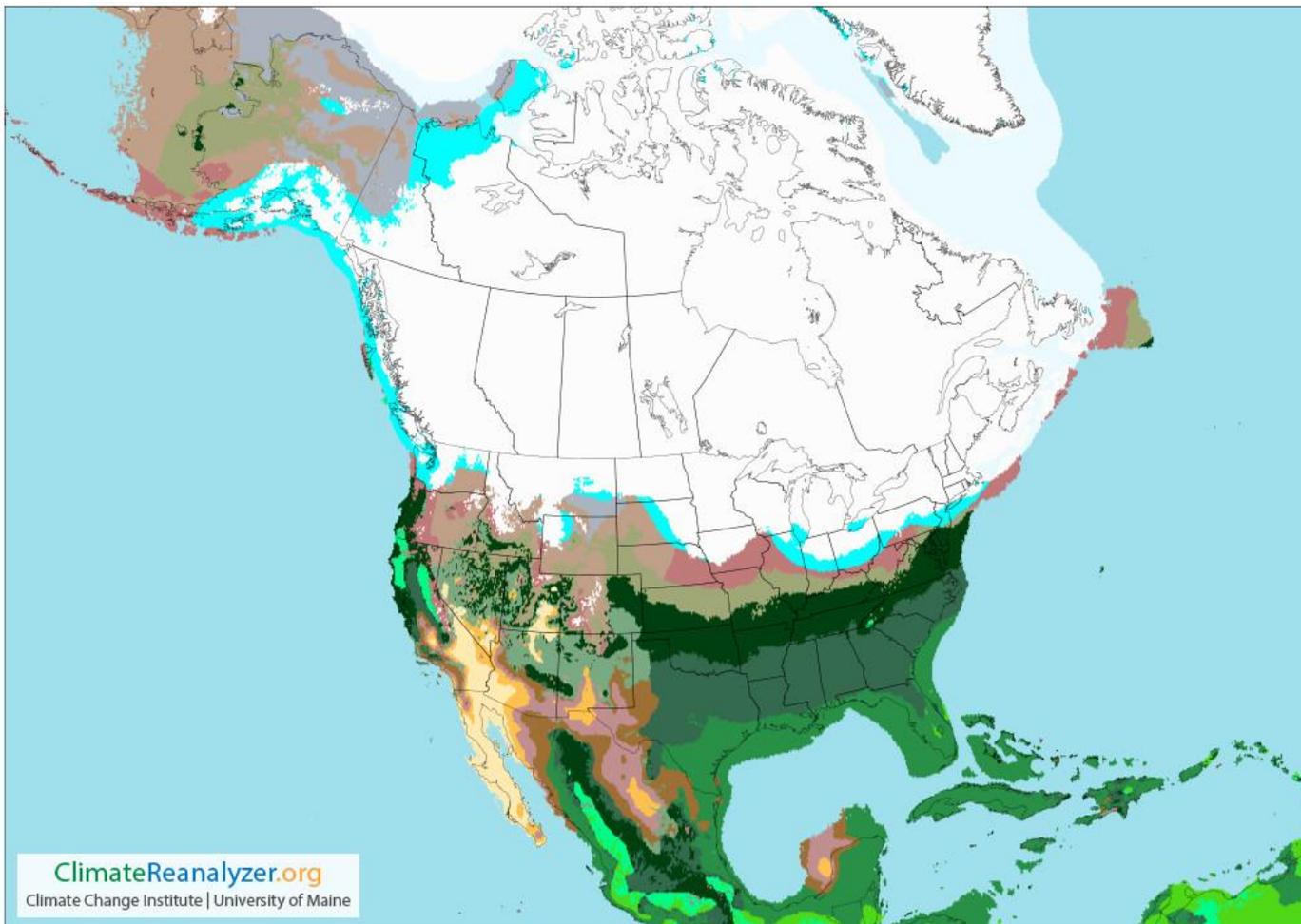
Potential Biomes

- | | | | | | |
|--|-----------------------|--|--------------------------|--|---------------------------|
| | Cool Conifer Forest | | Polar Desert | | Glacier Accumulation Zone |
| | Mixed Forest | | Dry Tundra or Alpine | | Glacier Ablation Zone |
| | Warm Broadleaf Forest | | Moist Tundra or Alpine | | Sea Ice |
| | Temperate Rainforest | | Forest-Tundra Transition | | Water |
| | Tropical Rainforest | | Cool Steppe | | |
| | Tall Grass Prairie | | Steppe | | |
| | Short Grass Prairie | | Low Latitude Desert | | |

Global $\Delta T = -6^{\circ}\text{C}$

Last Glacial Maximum

Equilibrium



ClimateReanalyzer.org
Climate Change Institute | University of Maine

Environmental Change Model, Version 2015A

Potential Biomes



Recent Weather Extremes

Ice Storm of December, 2013. The most damaging since 1998.

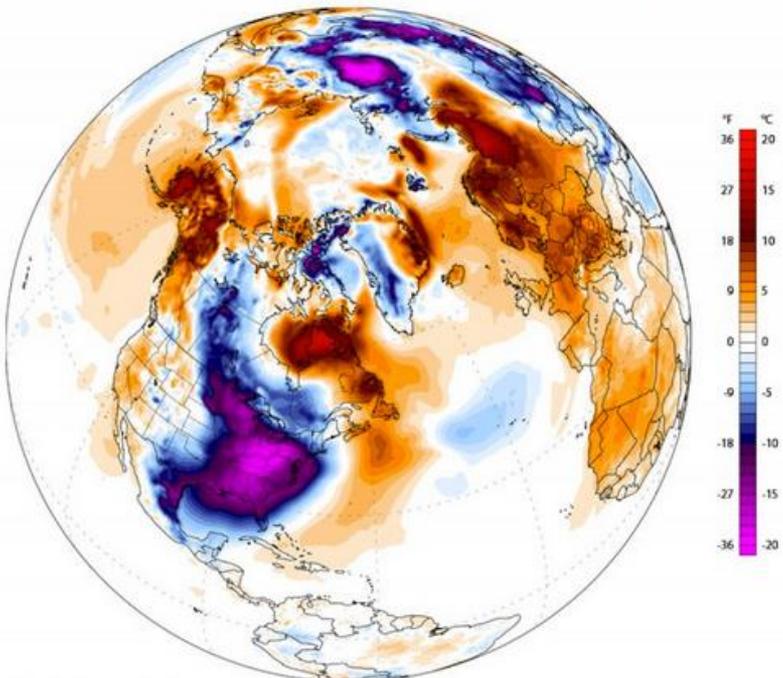


This Image Shows How The Polar Vortex Has Split In Two

JENNIFER WELSH
JAN. 7, 2014, 1:32 PM 2,579 1

You can see in the image how the "polar vortex" has ripped apart and spread Arctic air down toward the equator.

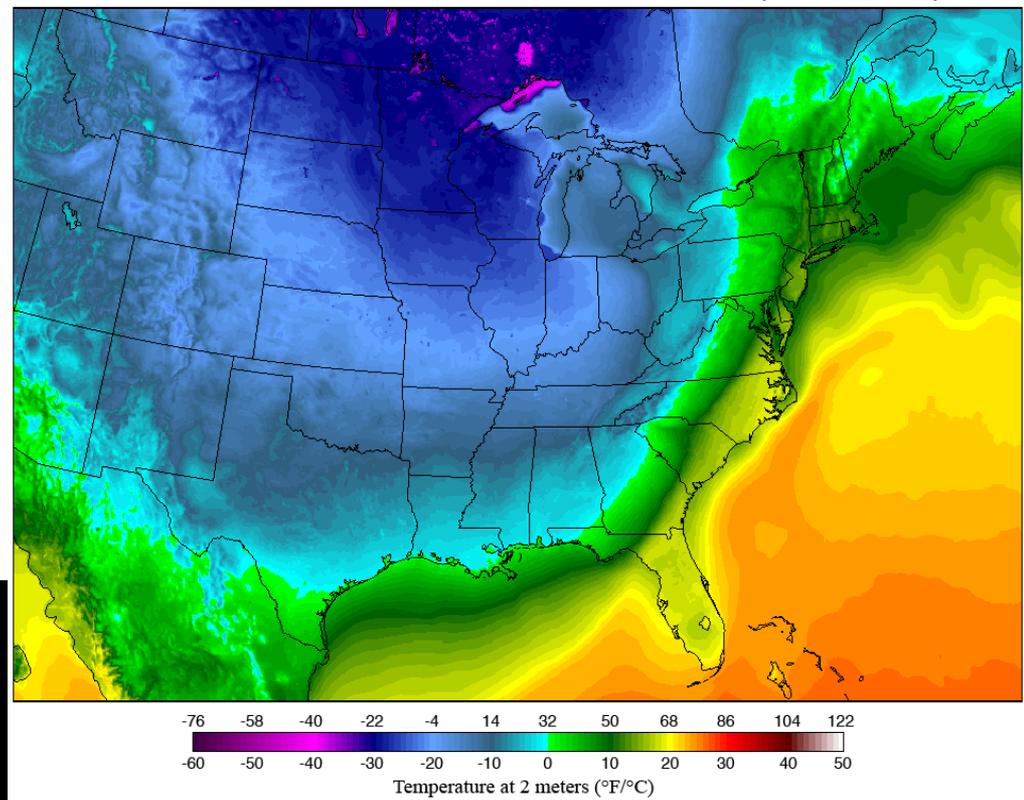
The purples are where the air is colder than average, while the orange and red are warmer than average, as you can see in the scale to the right. You can see one purple blob sitting over the U.S. East Coast and the other on the other side of the planet, above parts of Russia.



The Climate Beanalyzer | cci-reanalyzer.org

“Polar Vortex” January, 2014. Coldest winter across midwest and eastern U.S. since 1990s.

North American Mesoscale Model Monday 0900 EDT, January 06, 2014



The Climate Beanalyzer | cci-reanalyzer.org

Summer in March, 2012, draws to a close

By: [Dr. Jeff Masters](#) , 4:54 PM GMT on March 23, 2012

51 +

[Like](#) [+1](#) [Share this Blog](#)

The most incredible spring heat wave in U.S. and Canadian recorded history is finally drawing to a close today, after a ten-day stretch of unprecedented record-smashing intensity. Since record keeping began in the late 1800s, there have never been so many spring temperature records broken, and by such a large margin. Airports in fifteen different states have set all-time records for March warmth, which is truly extraordinary considering that the records were set in the middle of the month, instead of the end of the month. The 29.2°C [85°F] measured at Western Head, Nova Scotia yesterday was the third warmest temperature ever recorded in Canada in March, according to Environment Canada and weather records researcher Maximiliano Herrera (top two records: 31.1°C at Alberini Beaver Creek BC on March 29th 1926, and 29.4°C in 1921 at Wallaceburg.) Michigan's all-time record for March warmth was toppled on Wednesday, when the mercury hit 90°F at Lapeer. The previous record, 89° at Lapeer in 1910, was matched at three stations yesterday--Ypsilanti, Dearborn, and Lapeer. The duration, areal size, and intensity of the Summer in March, 2012 heat wave are simply off-scale, and the event ranks as one of North America's most extraordinary weather events in recorded history. Such a historic event is difficult to summarize, and in today's post I will offer just a few of the most notable highlights.

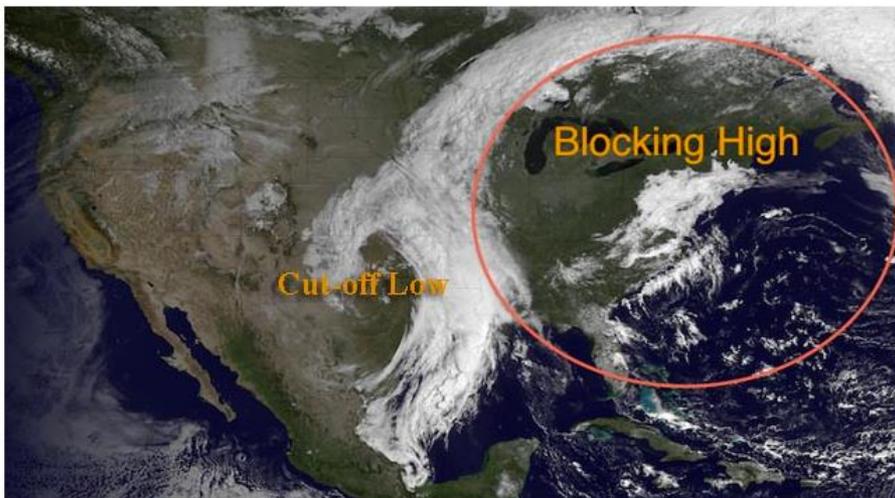


Figure 1. Clear skies over the Eastern U.S. caused by a blocking ridge of high pressure on March 21, 2012, are apparent in this visible satellite image. The comma-shaped cloud pattern over the Central U.S. is associated with a "cut-off" low pressure system. This low is moving over the Eastern U.S. today through Saturday, and will bring an end to "Summer in March" over the U.S. and Canada. Image credit: [NOAA's Environmental Visualization Lab](#), and modified by Andrew Freedman of [Climate Central](#).

Summer-In-March, 2012

March 18th, 2012

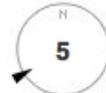


New March 21st daytime high temperature record for Bangor: **81 ° F** – this beat the old record by **17 ° F** !

Orono Weather at a Glance

Weather Station: **Bangor (KBGR)** | Elevation: **190 ft** Station Select

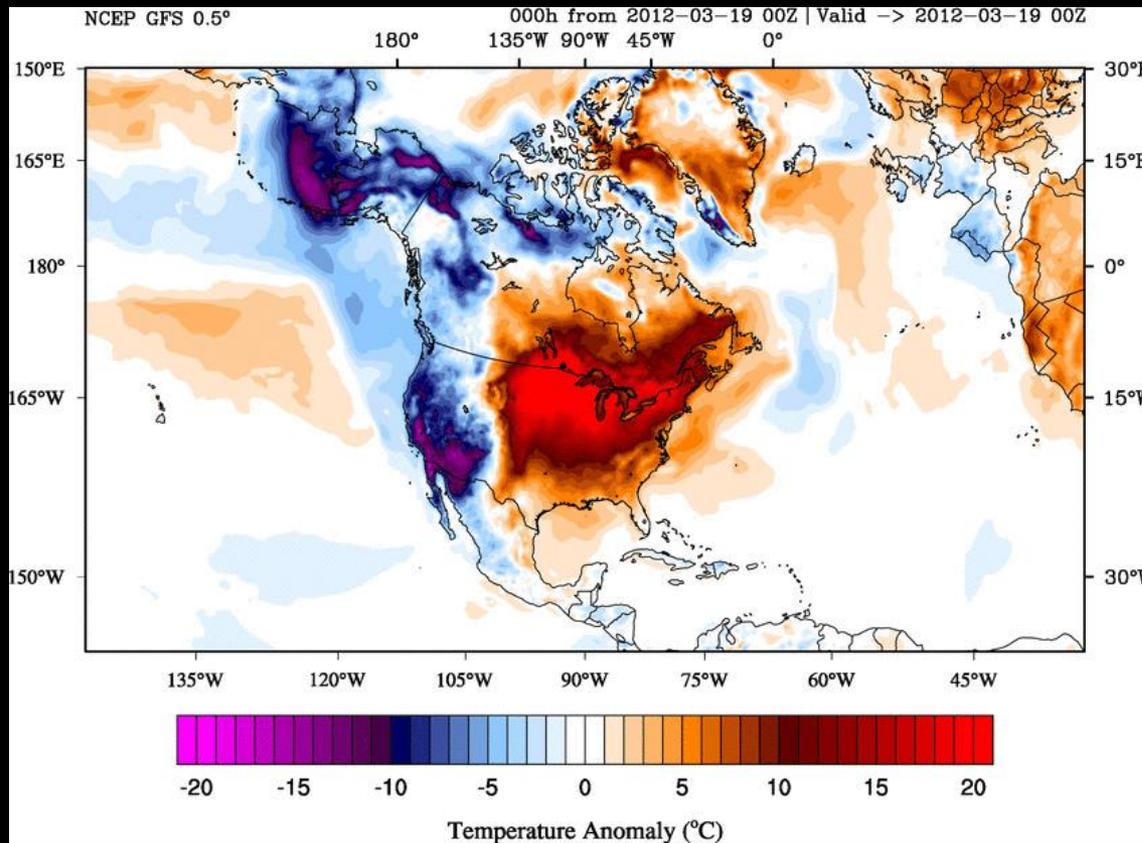
Now Temperature Wind(mph) Sunrise / Set Moon

 **Clear** **57 °F**  **5**  **6:35 AM**  **Waning Crescent**

Feels Like 57 °F  **6:49 PM** [More Astronomy](#)

Today	Tonight	Tomorrow	Friday	Saturday	Sunday
 81 °F Partly Cloudy	 54 °F Partly Cloudy	 81 46 °F Chance of Rain 20% chance of precipitation	 57 32 °F Partly Cloudy	 50 37 °F Partly Cloudy	 59 30 °F Mostly Cloudy

Today is forecast to be **Warmer** than yesterday. [10-Day Forecast](#) - [Hourly Forecast](#)



History & Almanac

March 21, 2012	Max Temp	Min Temp
Normal	42 °F	24 °F
Record	64 °F (1946)	2 °F (1986)
Yesterday	78 °F	34 °F

Yesterday's Heating Degree Days: **9**

Choose a date

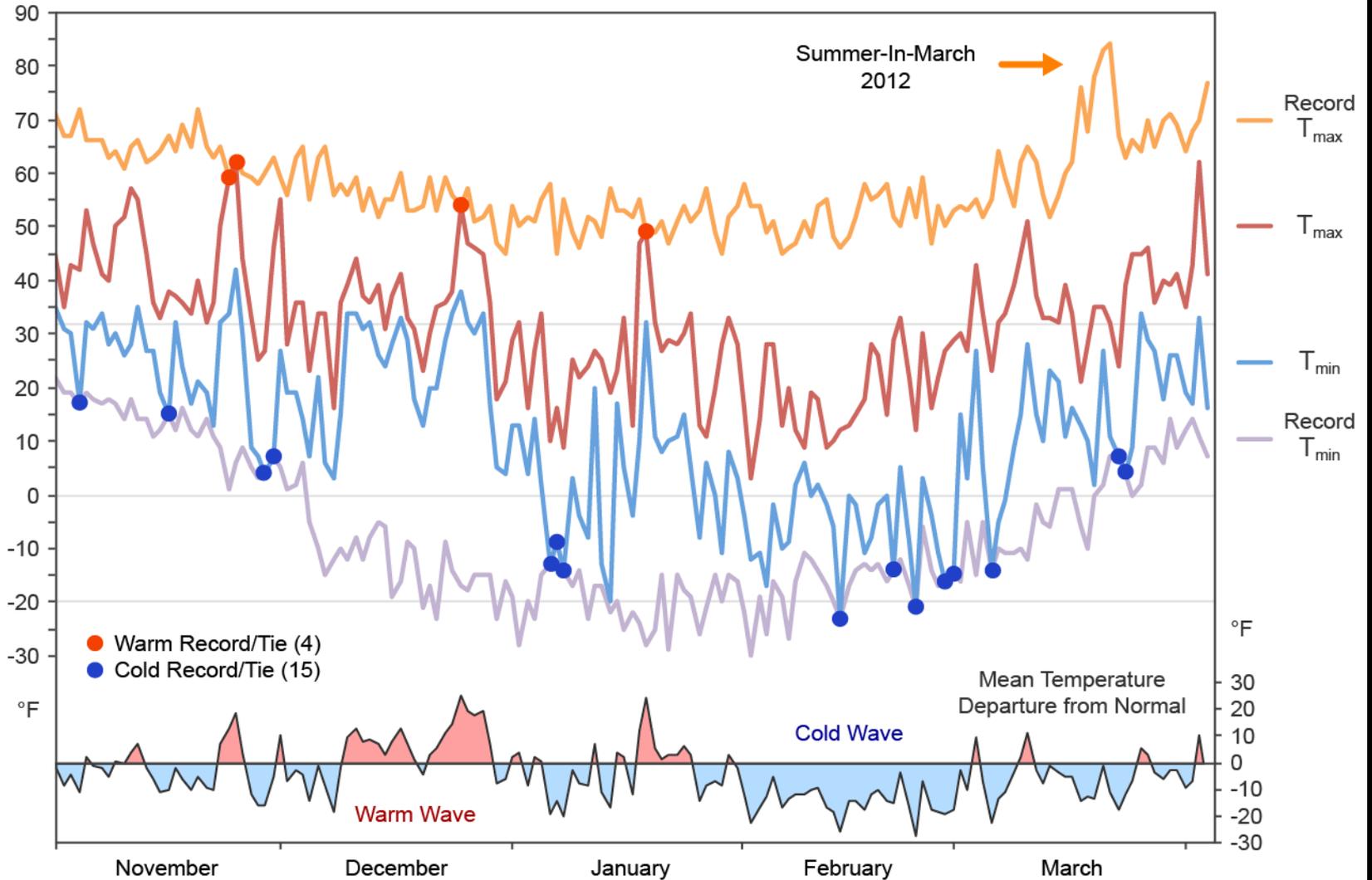
Aftermath of Summer-In-March, 2012



Extreme Low
Snow Cover
March 22, 2012

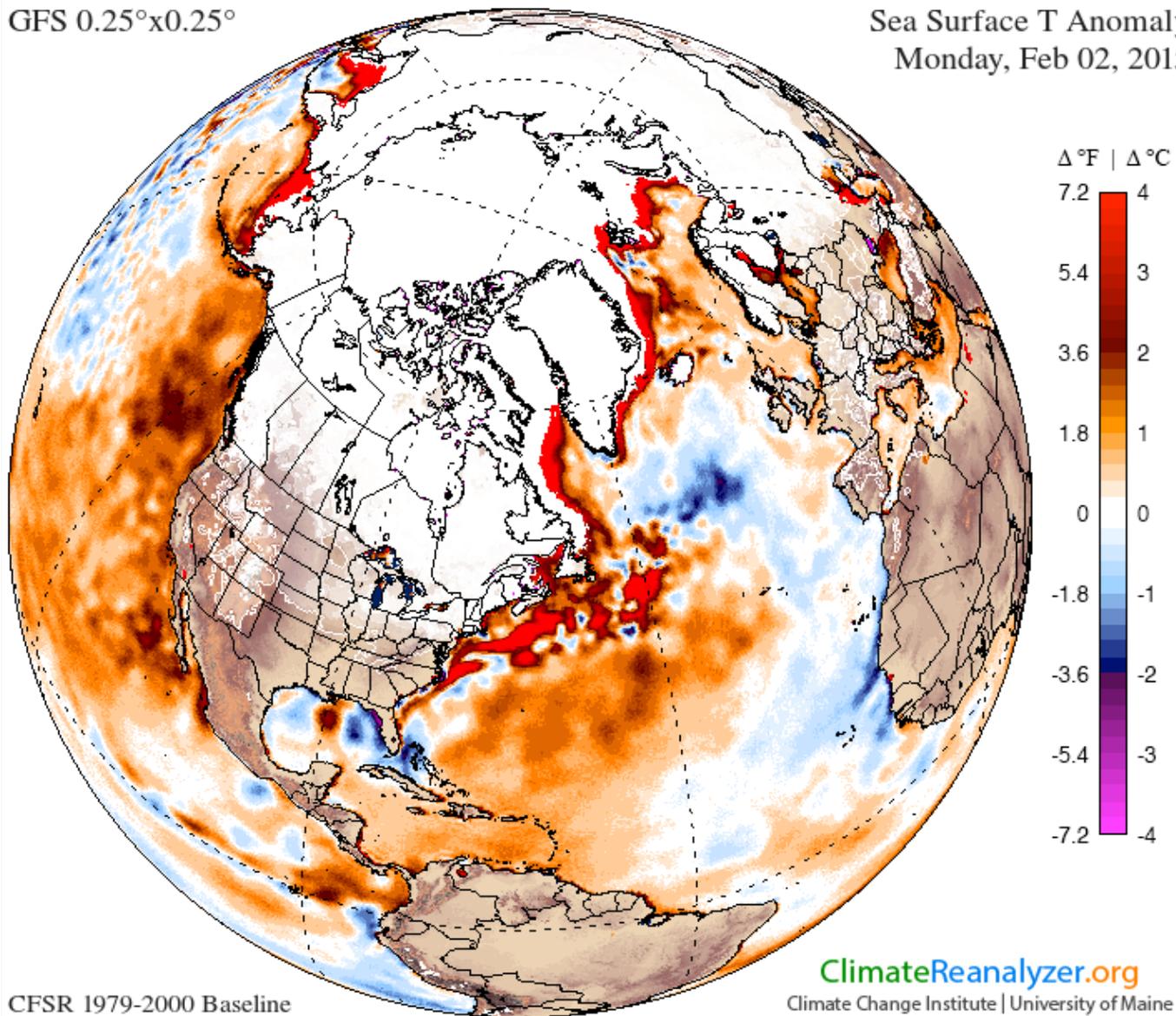


Temperature, Nov 2014 - Mar 2015 Recorded at Bangor International Airport



GFS 0.25°x0.25°

Sea Surface T Anomaly
Monday, Feb 02, 2015



World
+ 0.53 °C

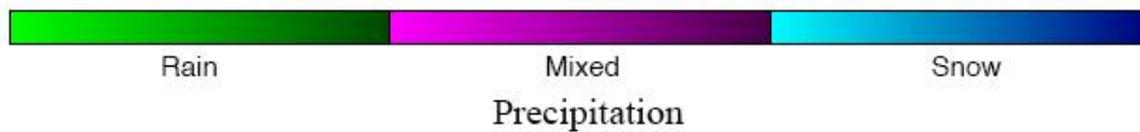
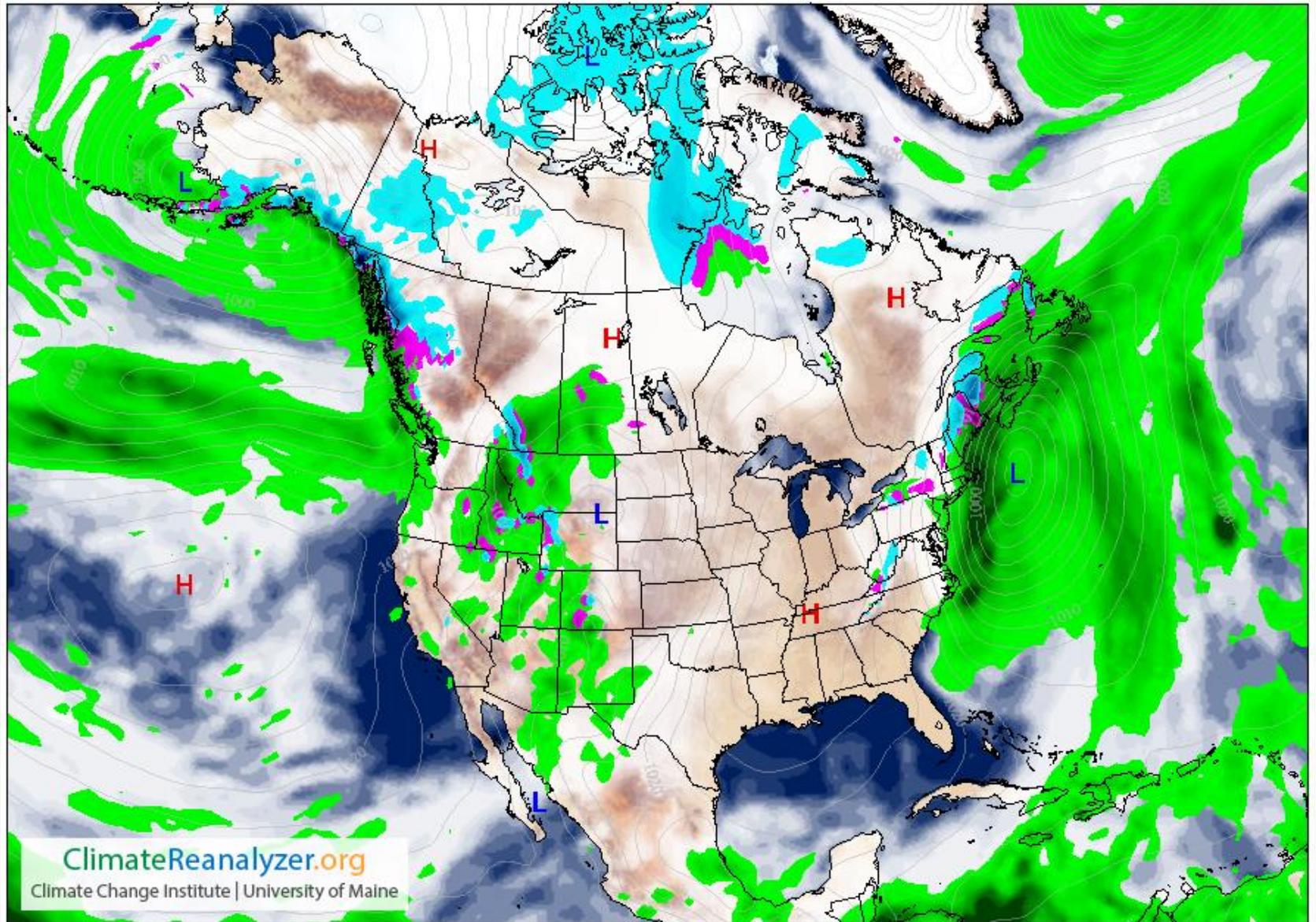
Northern Hemisphere
+ 0.64 °C

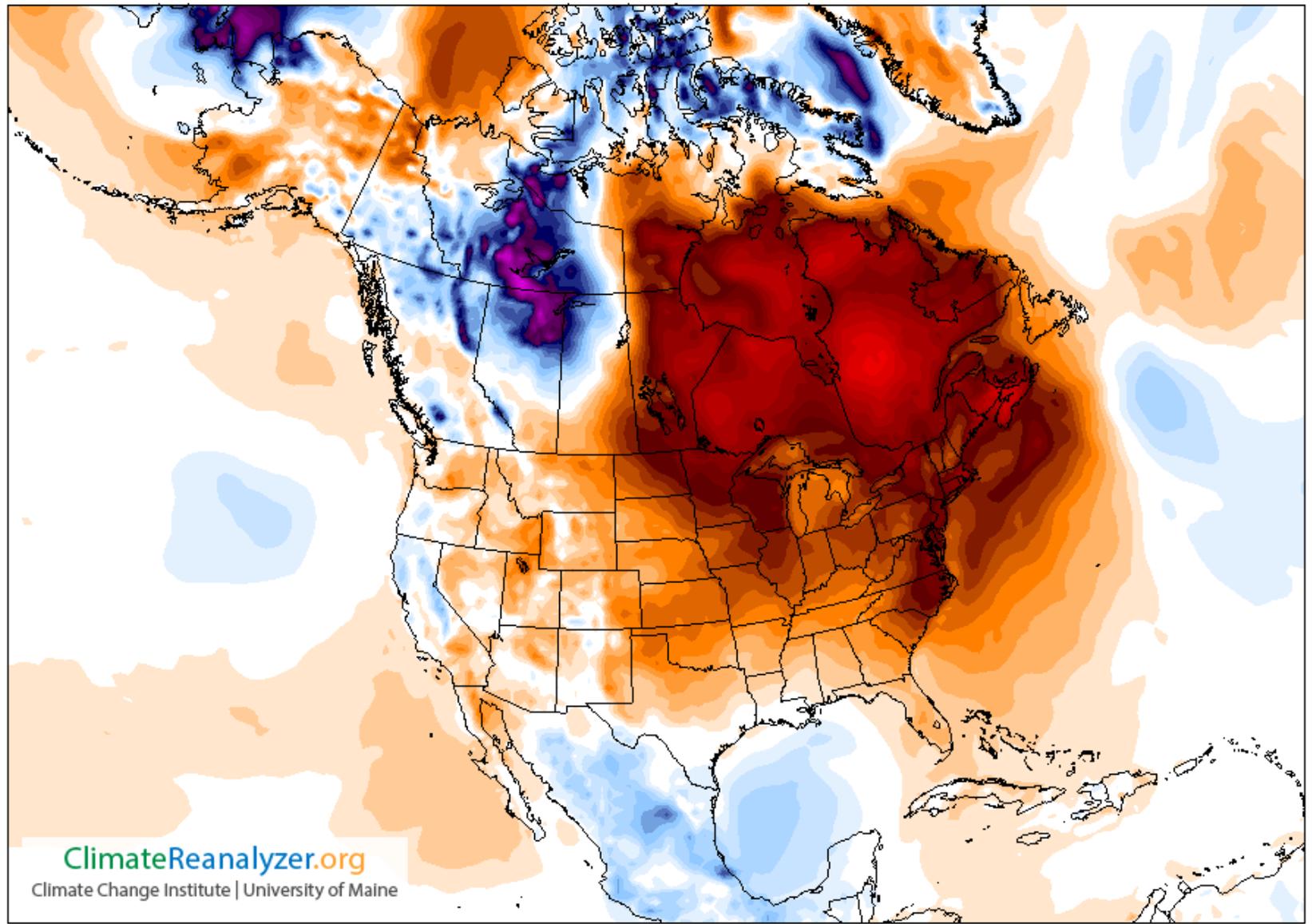
North Atlantic
+ 0.23 °C

Equatorial Pacific
+ 0.64 °C

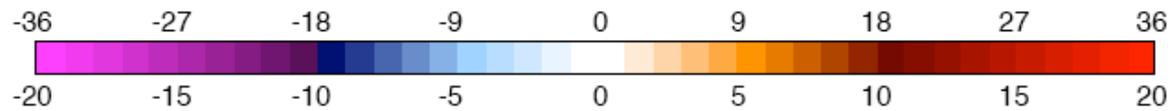
Southern Hemisphere
+ 0.43 °C

North Pacific
+ 0.45 °C



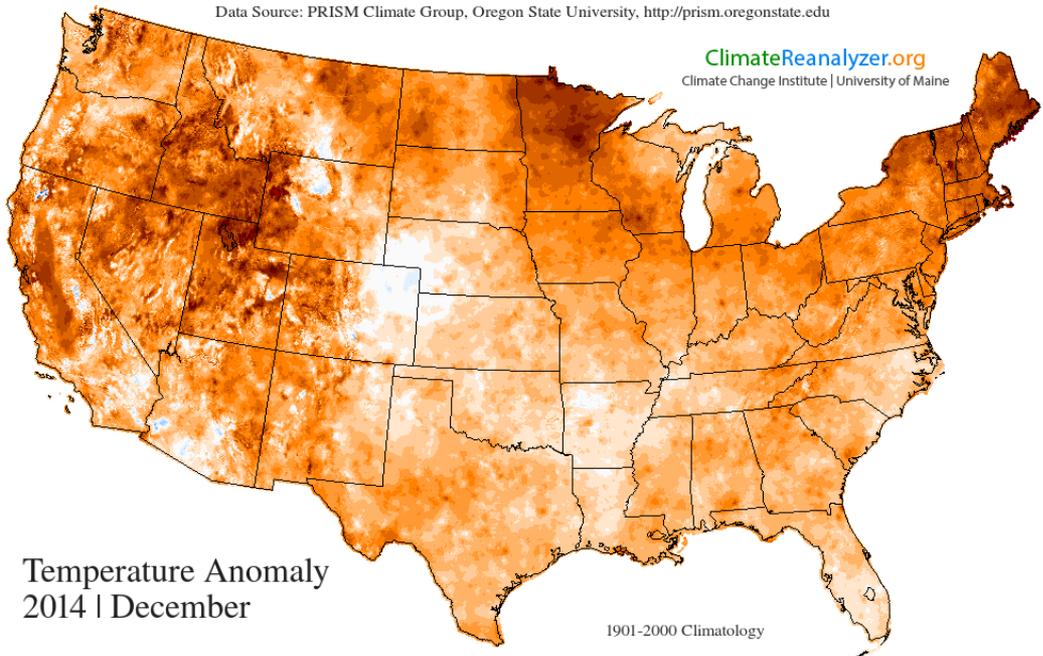


ClimateReanalyzer.org
Climate Change Institute | University of Maine

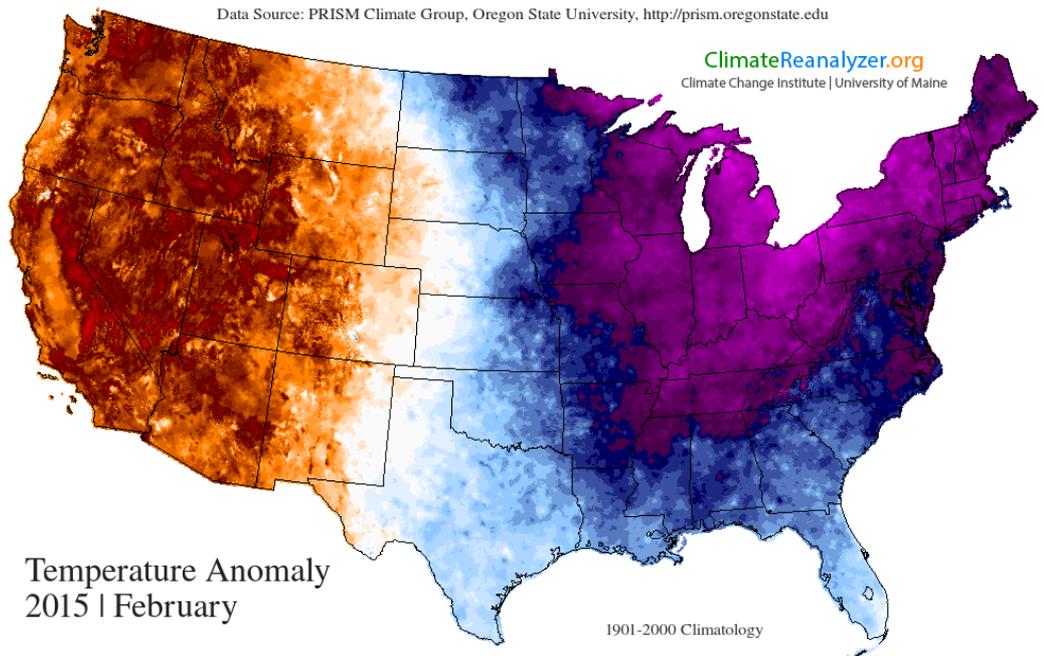


Temperature Anomaly (°F/°C)

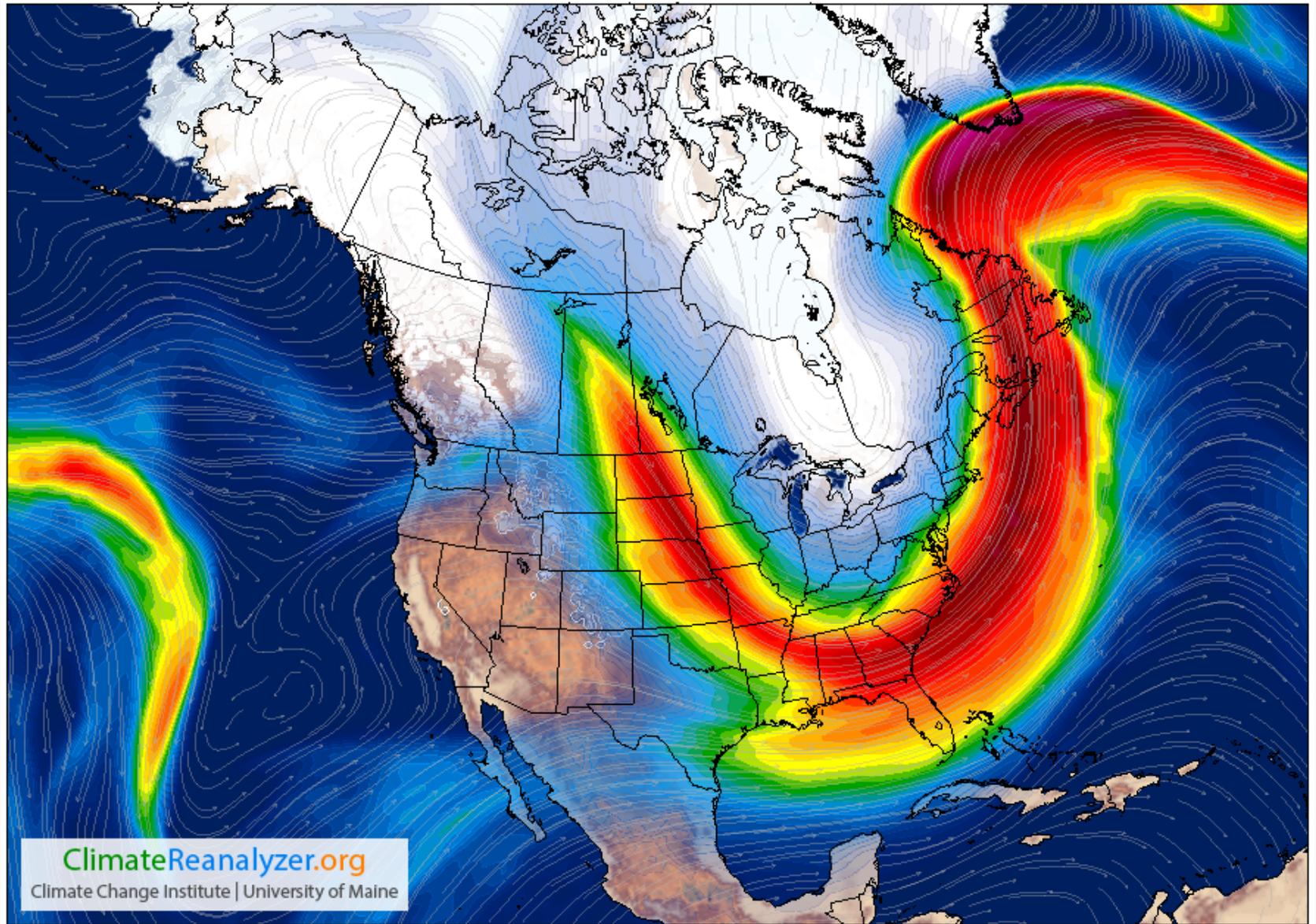
CFSR 1979-2000 Baseline



Temperature Anomaly
2014 | December



Temperature Anomaly
2015 | February



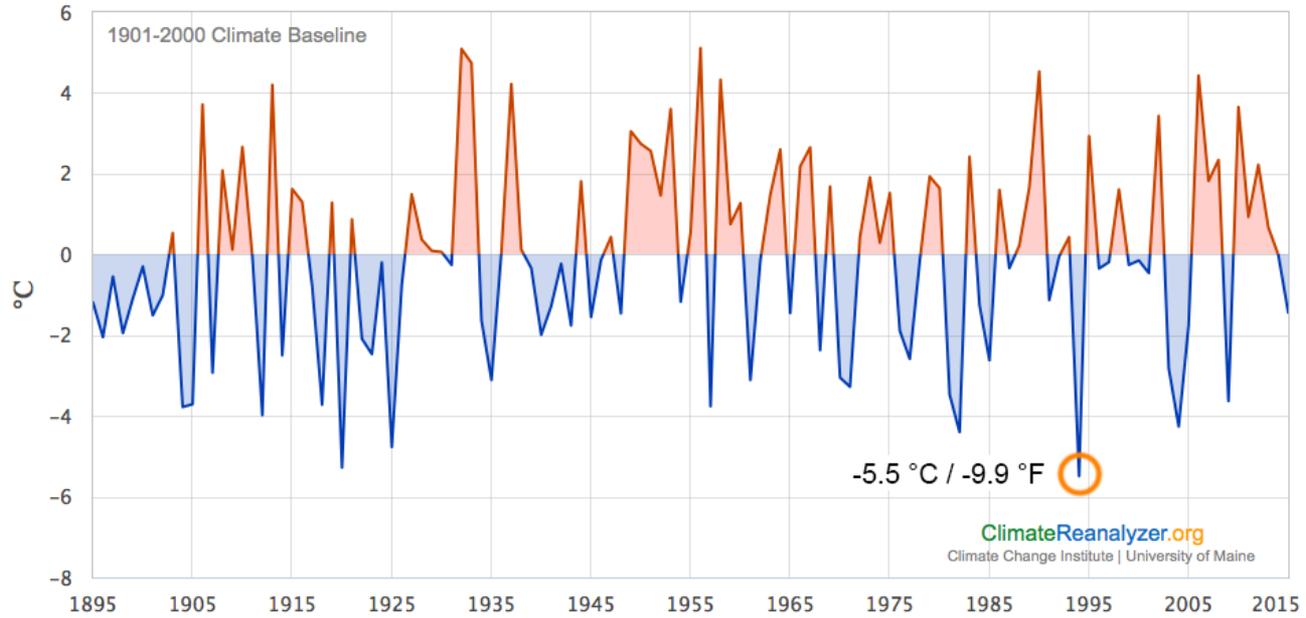
ClimateReanalyzer.org
Climate Change Institute | University of Maine



Wind Speed at 250 millibar (m/s)

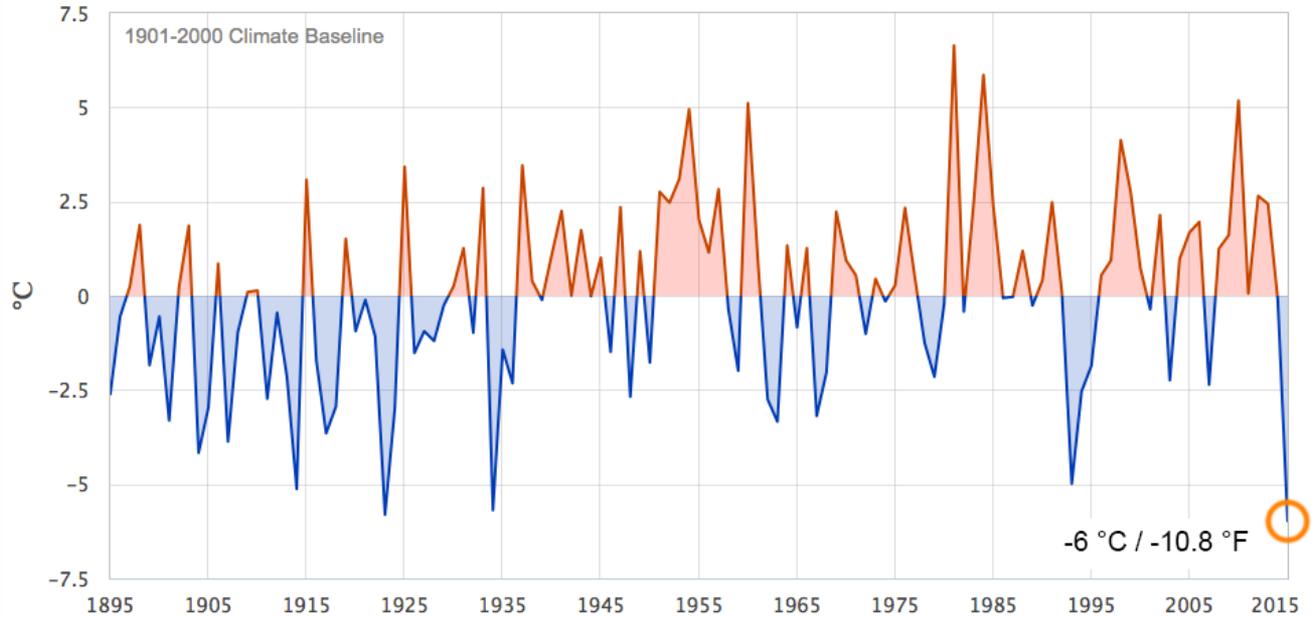
Maine, USA January Avg. Temperature Anomaly

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



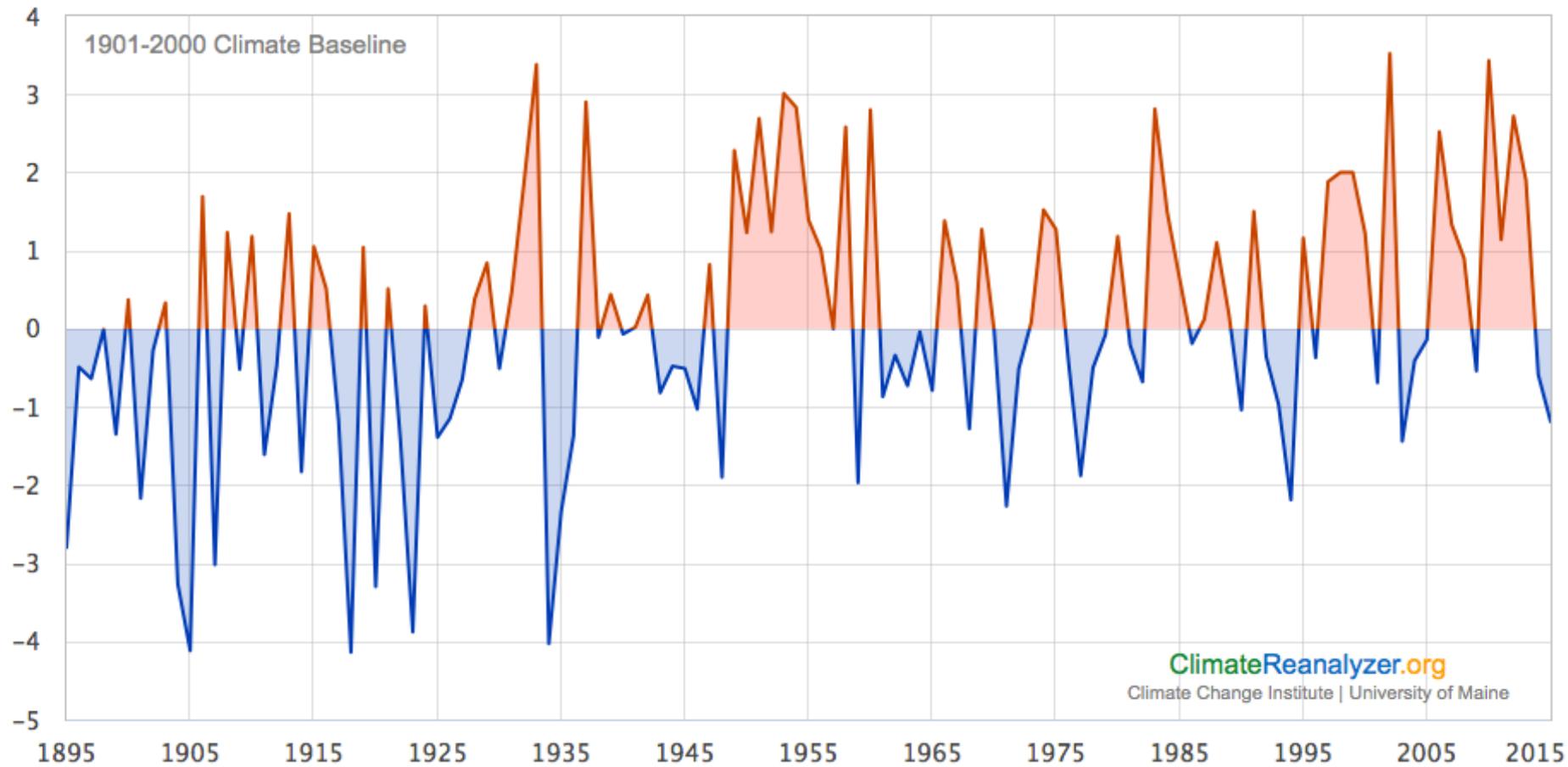
Maine, USA February Avg. Temperature Anomaly

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



Maine, USA Winter (DJF) Avg. Temperature Anomaly

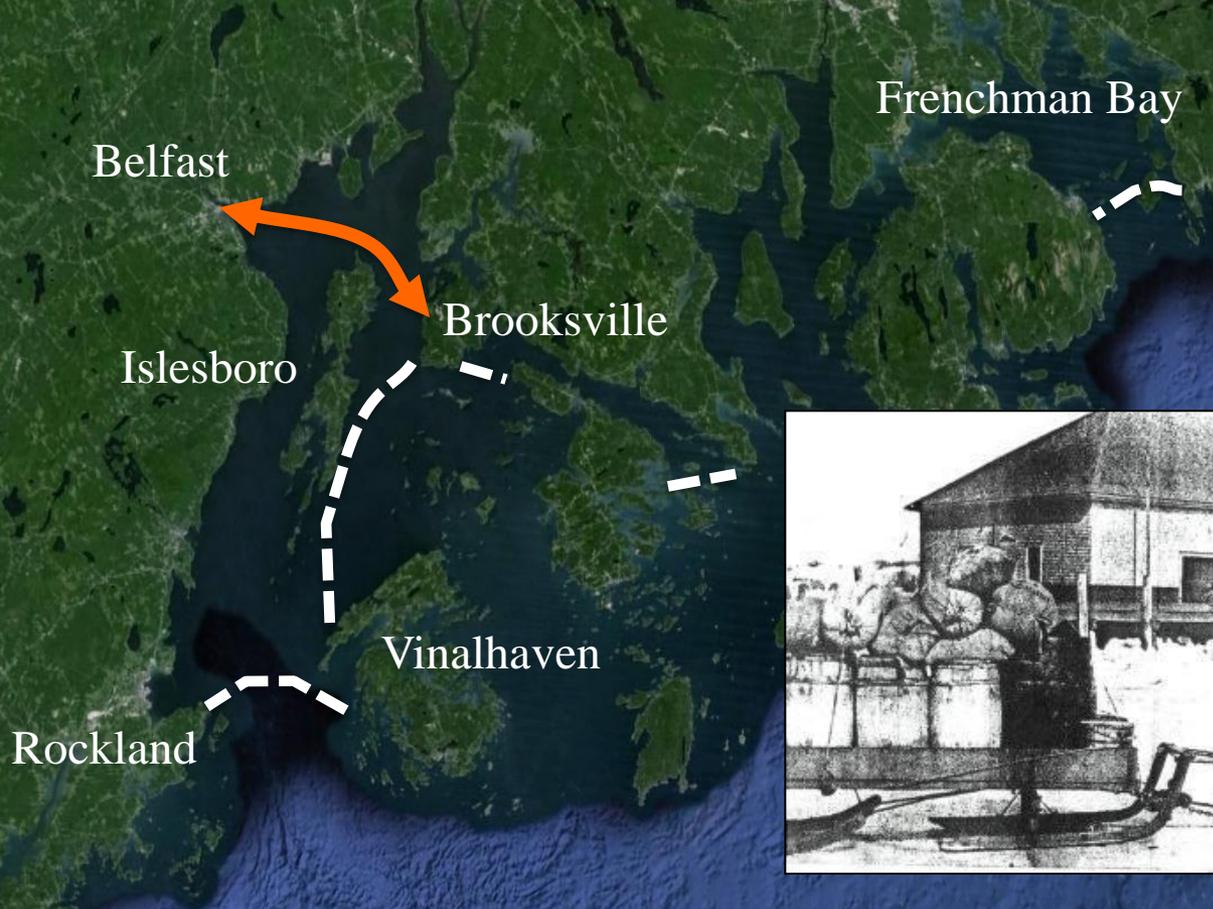
Data Source: PRISM Climate Group, Oregon State University, <http://prism.oregonstate.edu>



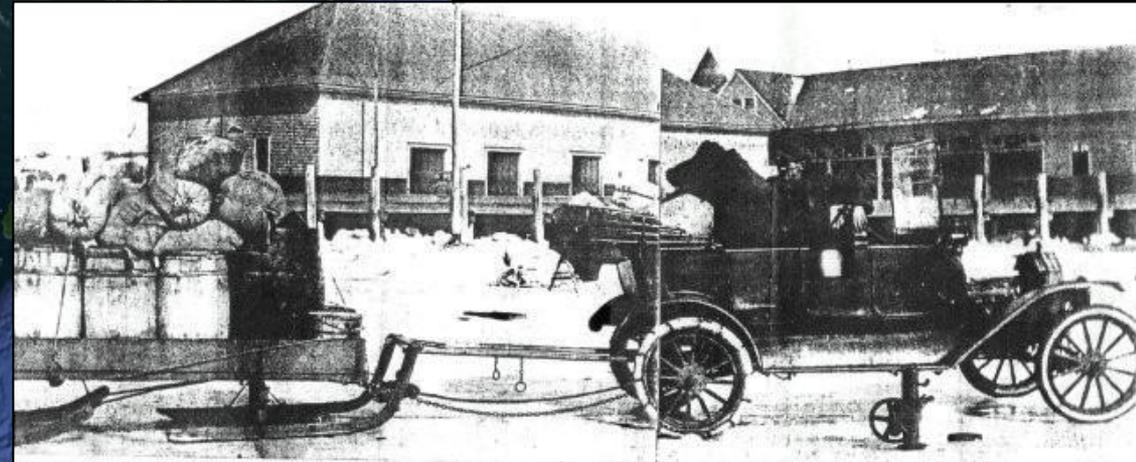
The Pemaquid stuck in ice off Bar Harbor, ca. 1880



Source: Maine Memory Network



Frenchman Bay



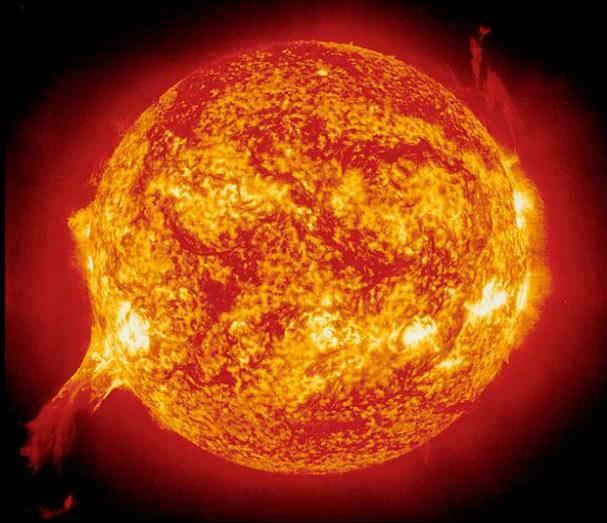
“Belfast, Feb 24 – Automobiling [sic] across the bay from Brooksville and the Castine has come to be a regular thing now. The pathfinder Ford which made history Friday by being the first car to cross the bay on the ice, made four trips Saturday to Brooksville, towing a horse-sled loaded with over a ton of grain and provisions and making the 12 miles across in about 25 minutes. The car took to the ice at Goose Falls, or Harborside, and same across to Turtle Head, then up the Belfast harbor...Other cars came over Sunday and Penobscot Bay turned into something of a boulevard. (Bangor Daily News, Feb. 1918)”

Source: <http://gen3antiqueauto.com/bayfroze.htm>



Branscom's Coal and Wood wharf in the winter of 1923, the last year all of Somes Sound and the Great Harbor froze over, making it possible to walk to Islesford. The laden schooner alongside the wharf is probably about to offload coal.

What driving stresses impact climate?



Solar Variability



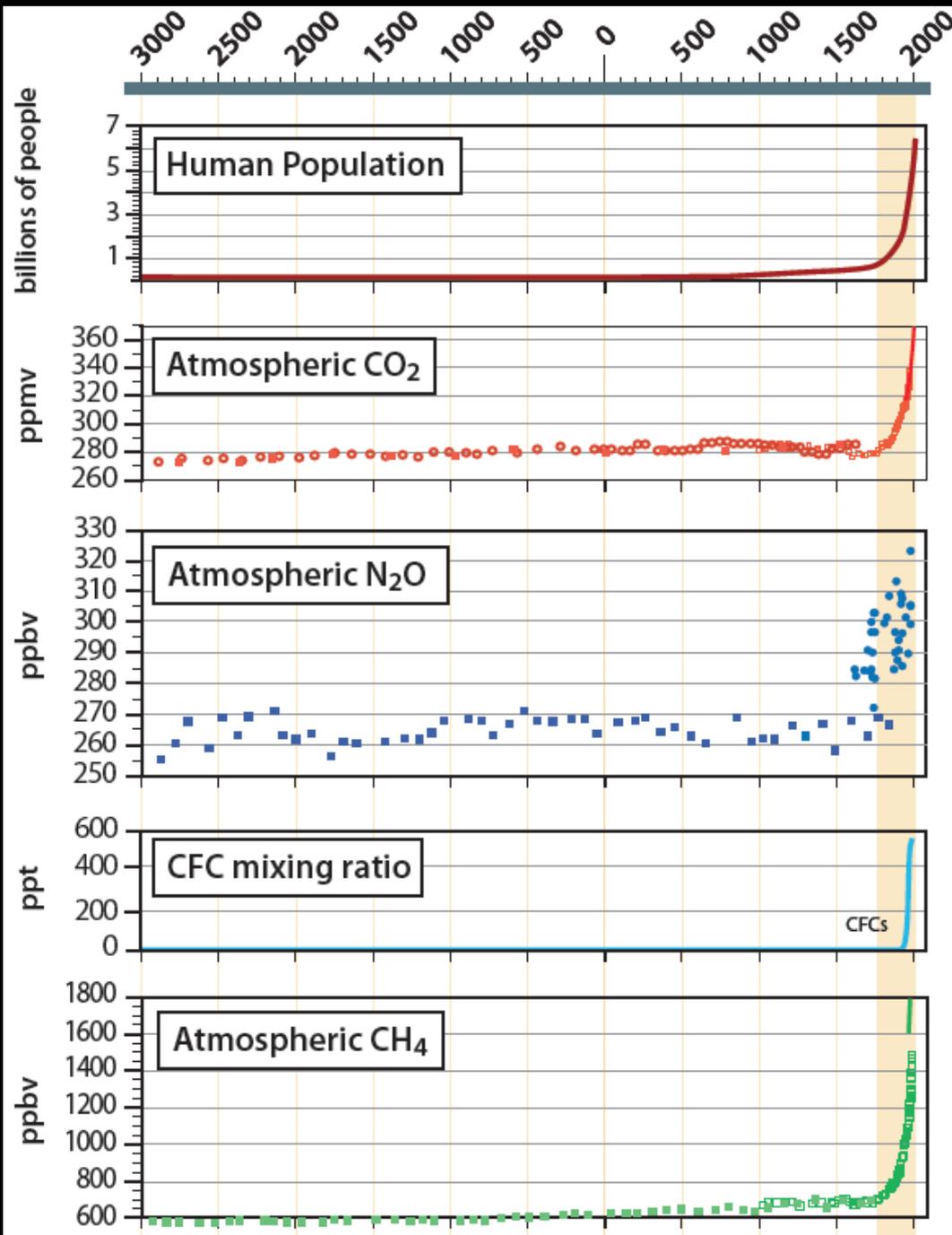
Volcanic Activity



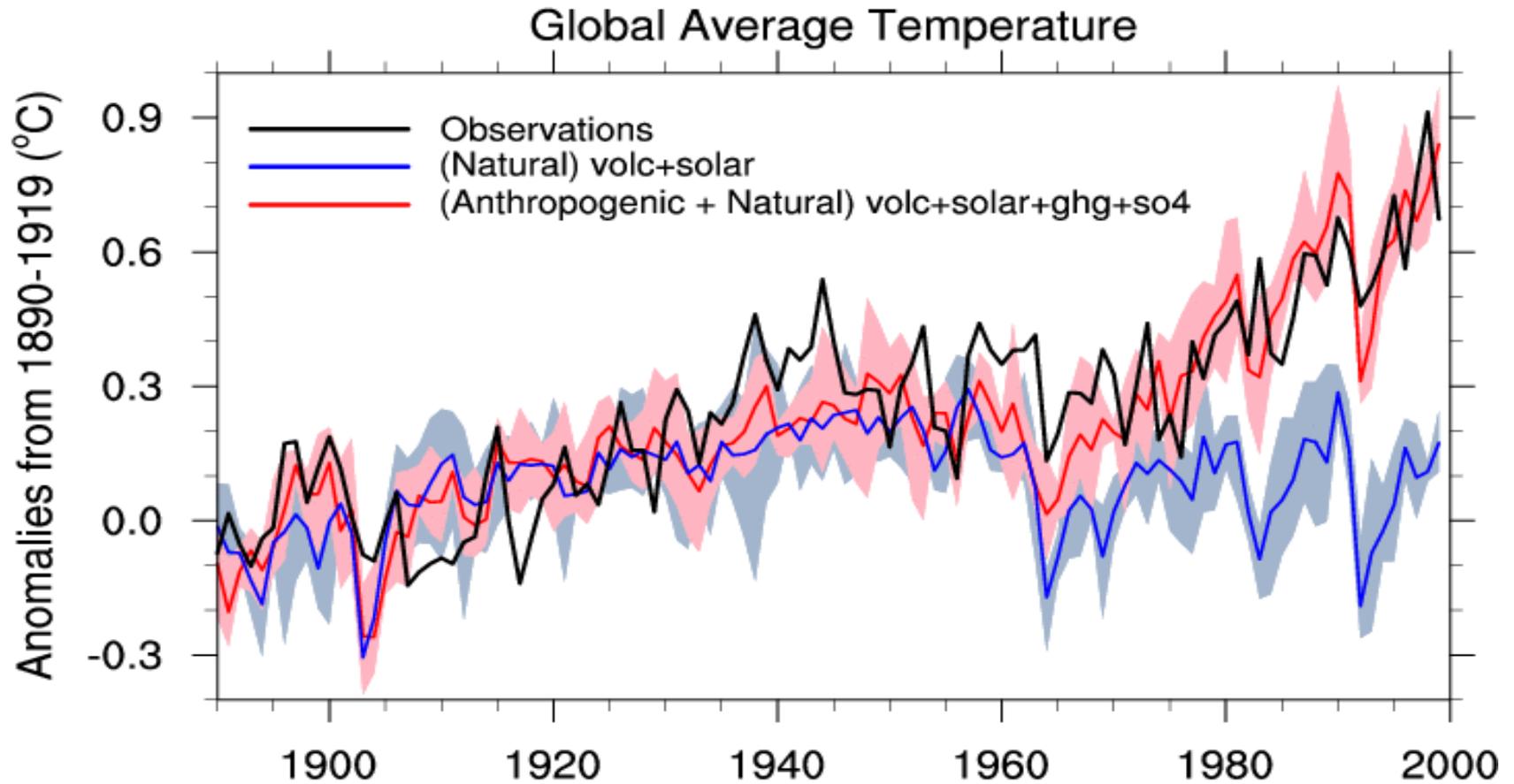
Industrial Emissions and Land Use



Dynamical Feedbacks



Natural forcings do not account for observed 20th Century warming after ~1960

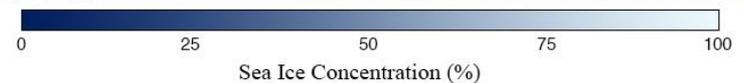
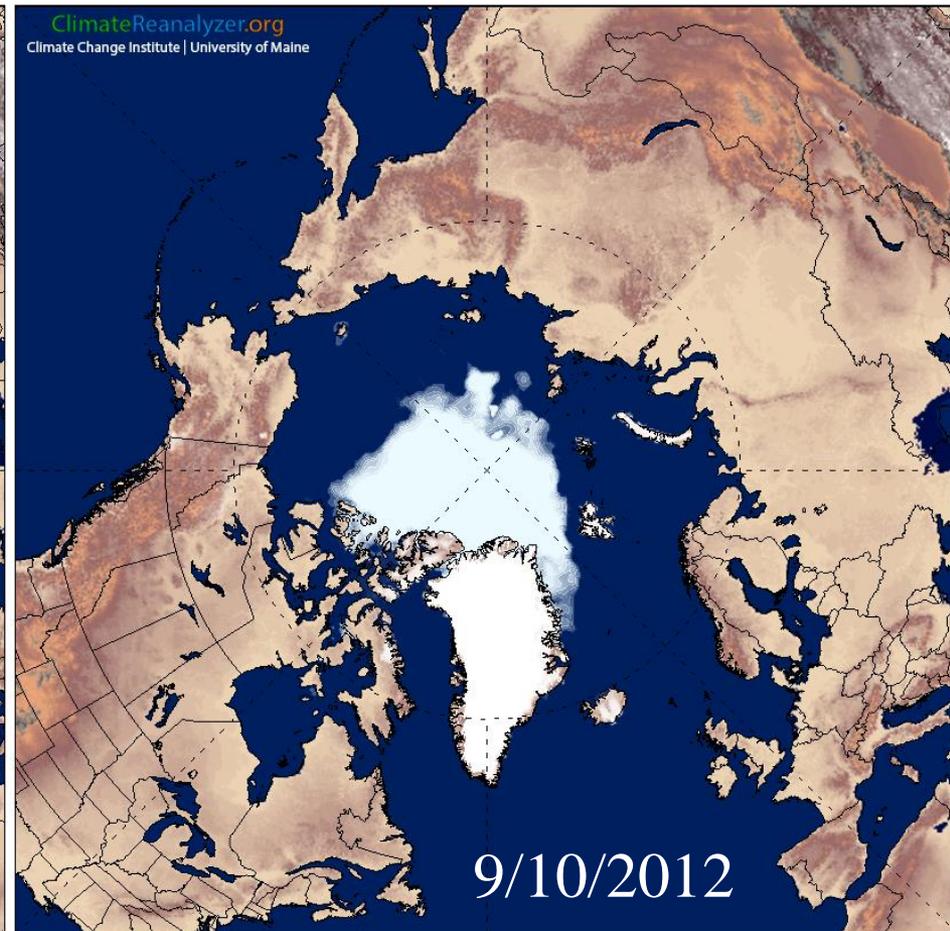
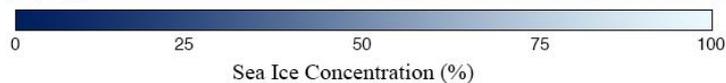
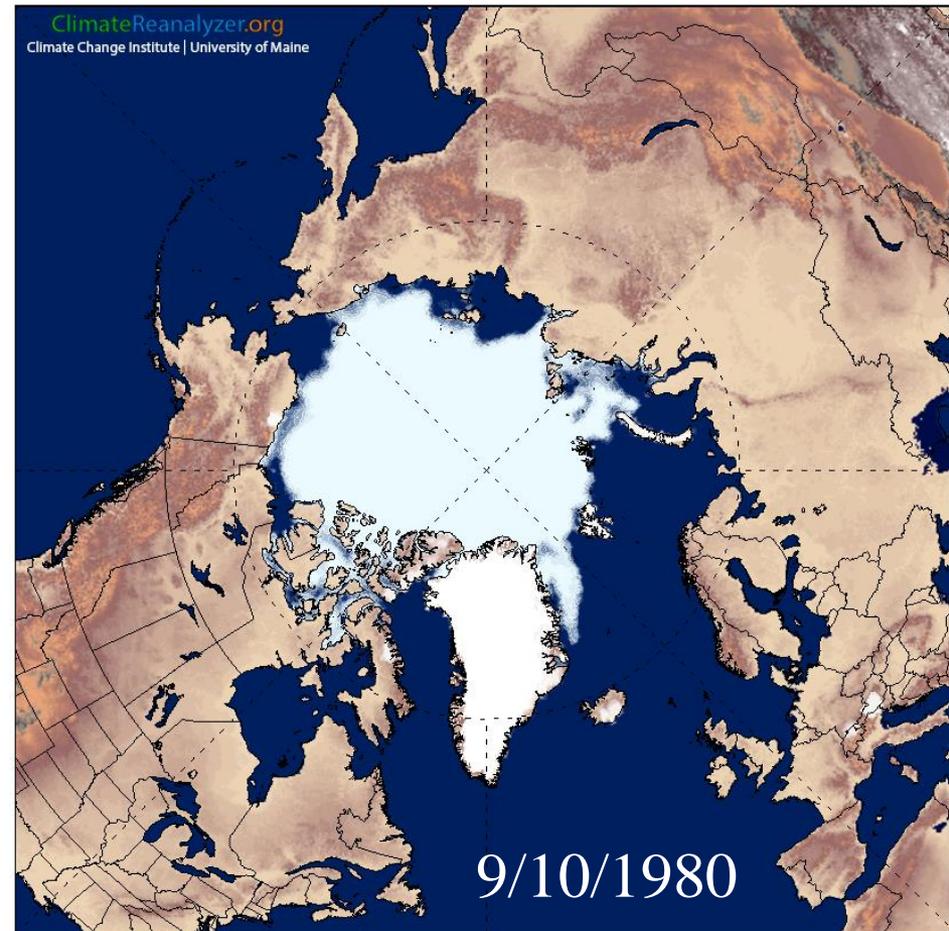


Extreme events of the past decade have been linked to the collapse of Arctic sea ice

NOAA/NSIDC (sea ice) | CFSR (snow)

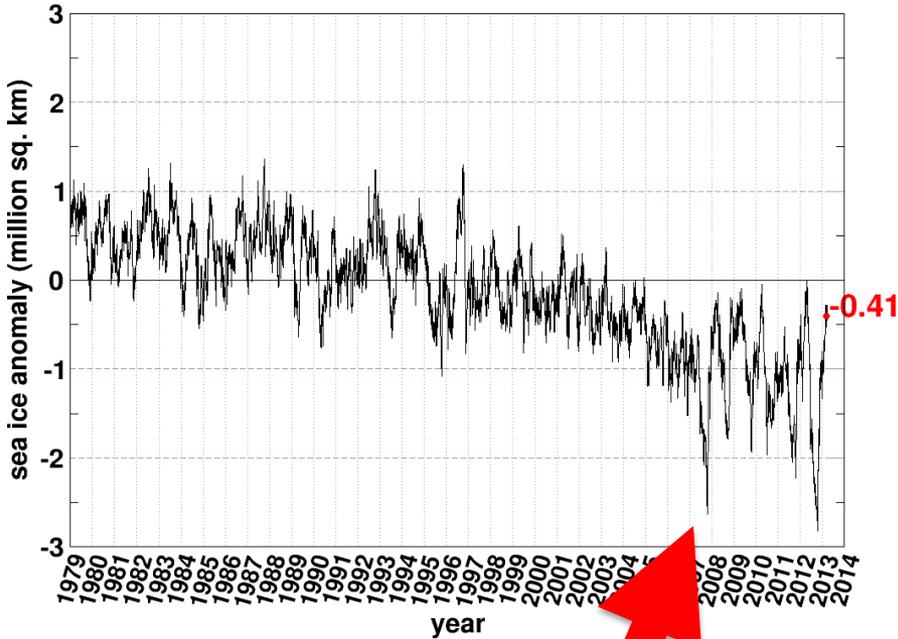
Wednesday, September 10, 1980 NOAA/NSIDC (sea ice) | CFSR (snow)

Monday, September 10, 2012



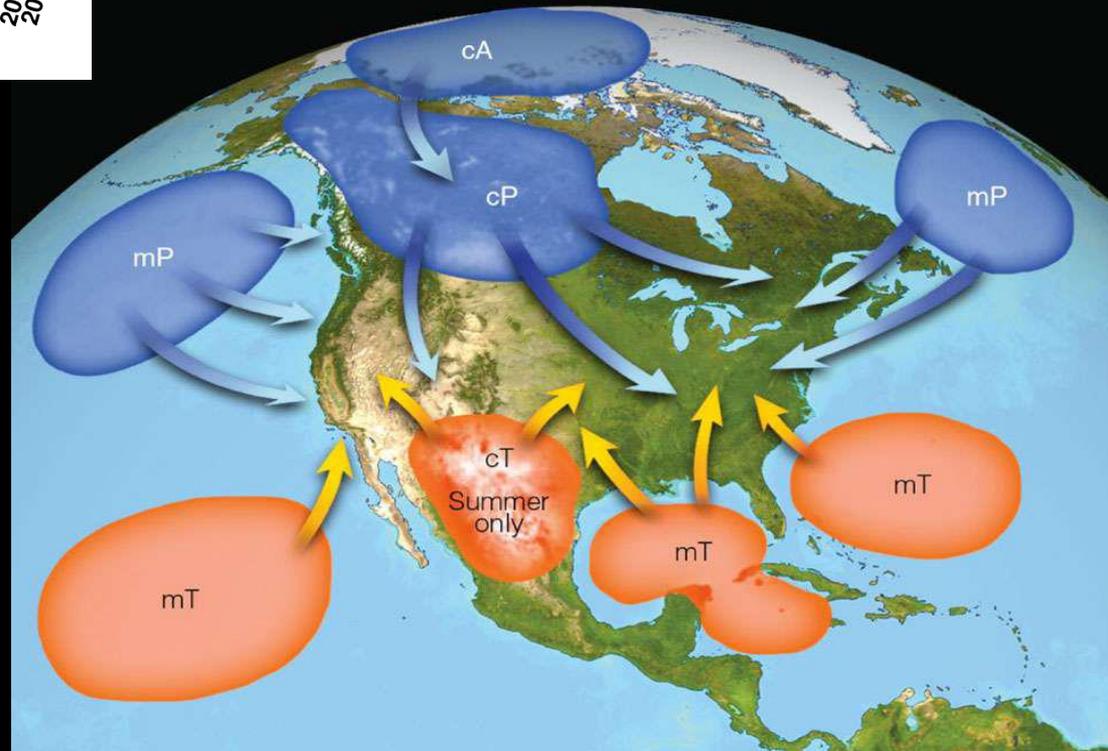
Northern Hemisphere Sea Ice Anomaly

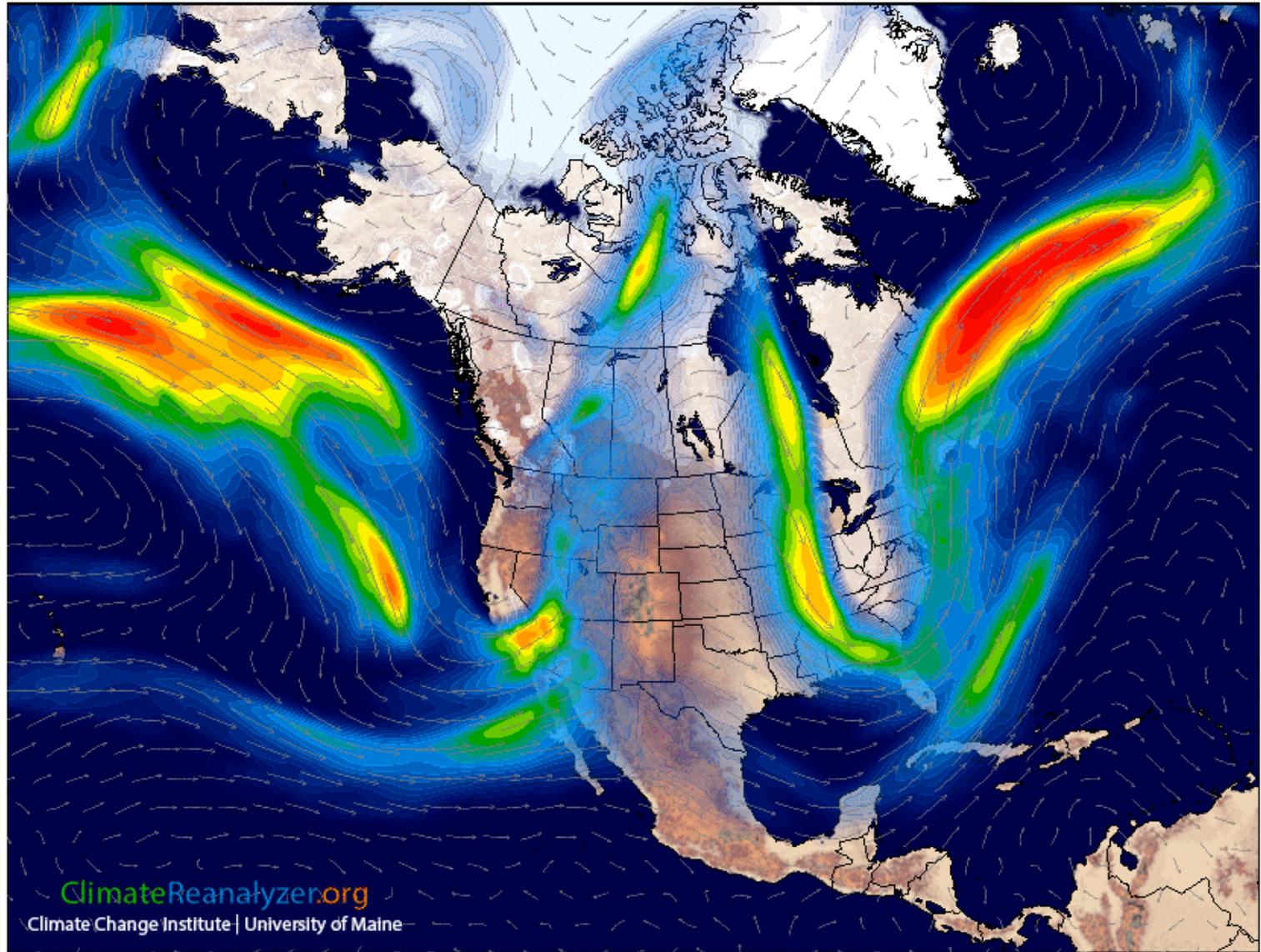
Anomaly from 1979-2008 mean



Maine Climate is Linked to Arctic Sea Ice

Major collapse of Arctic sea ice during the late summer of 2007. At that time, ~50% of ice area and volume remained compared to the long term average. A new record was set in 2012.





Wind Speed at 250 millibar (m/s)

North Atlantic Annual Sea Surface Temperature

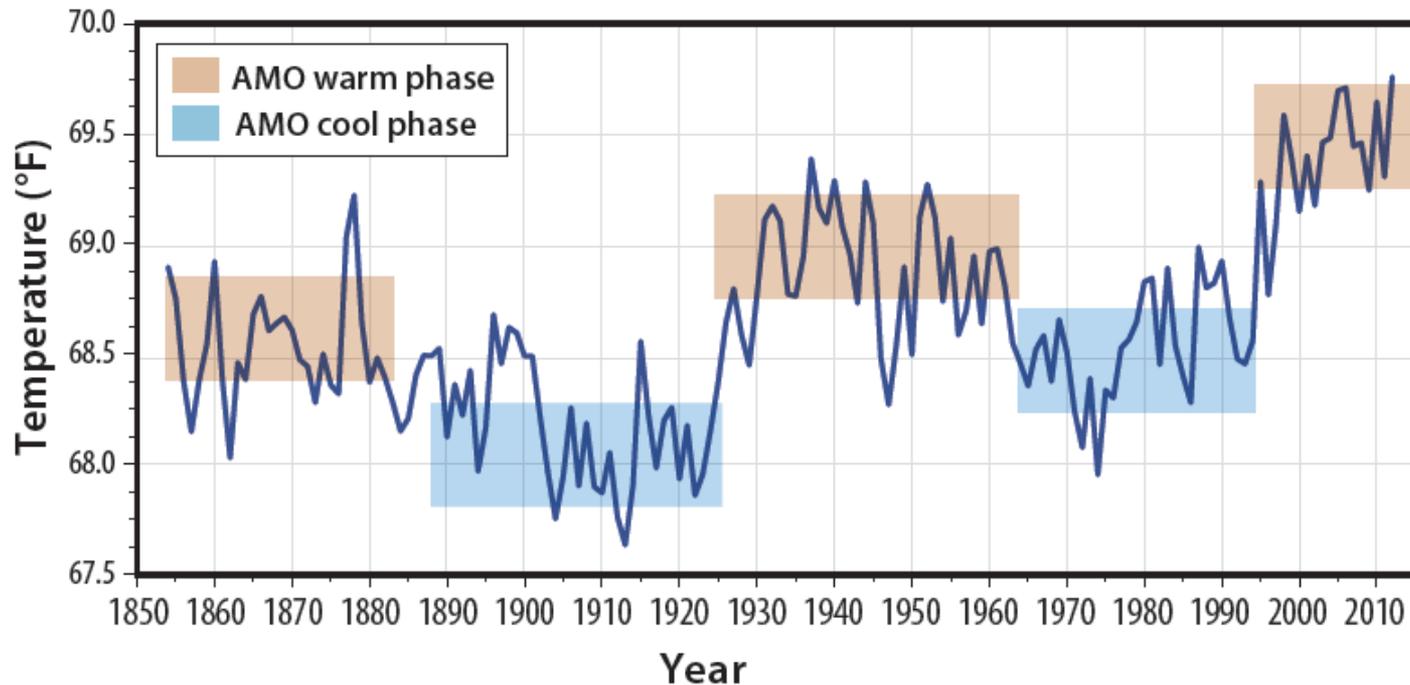
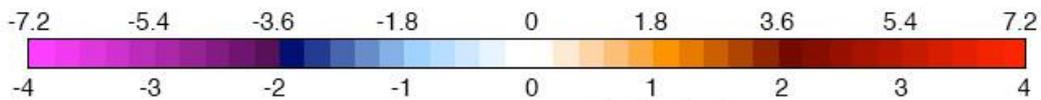
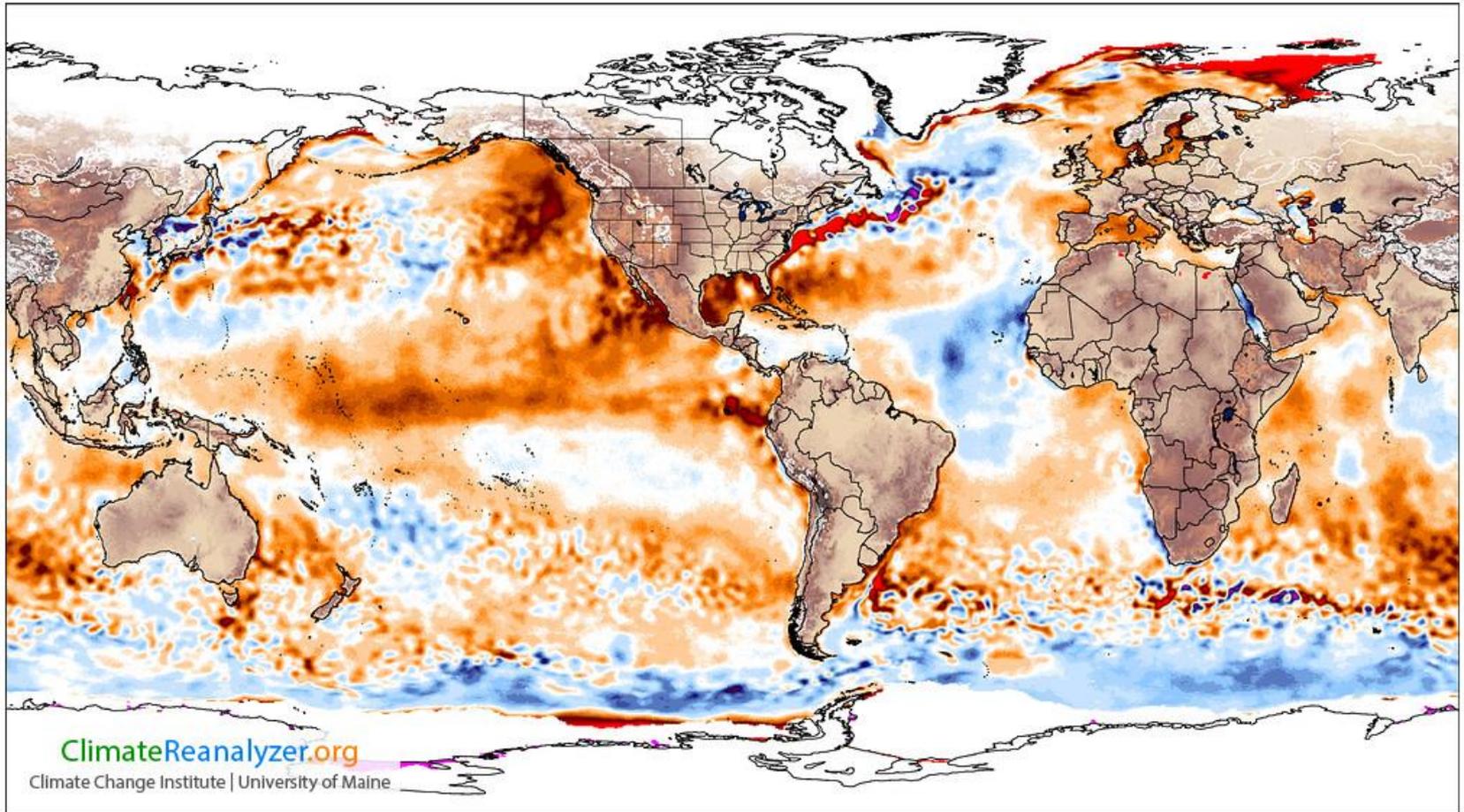


Figure 5. Mean annual sea surface temperature, 1854–2012, averaged across the North Atlantic Ocean (15°N–55°N, 80°W–0°E). Cool and warm phases of the Atlantic Multidecadal Oscillation are highlighted. Extended Reconstructed Sea Surface Temperature (ERSST) version 3b data provided by the NOAA/OAR/Earth System Research Laboratory Physical Sciences Division, Boulder, CO (esrl.noaa.gov/psd/).

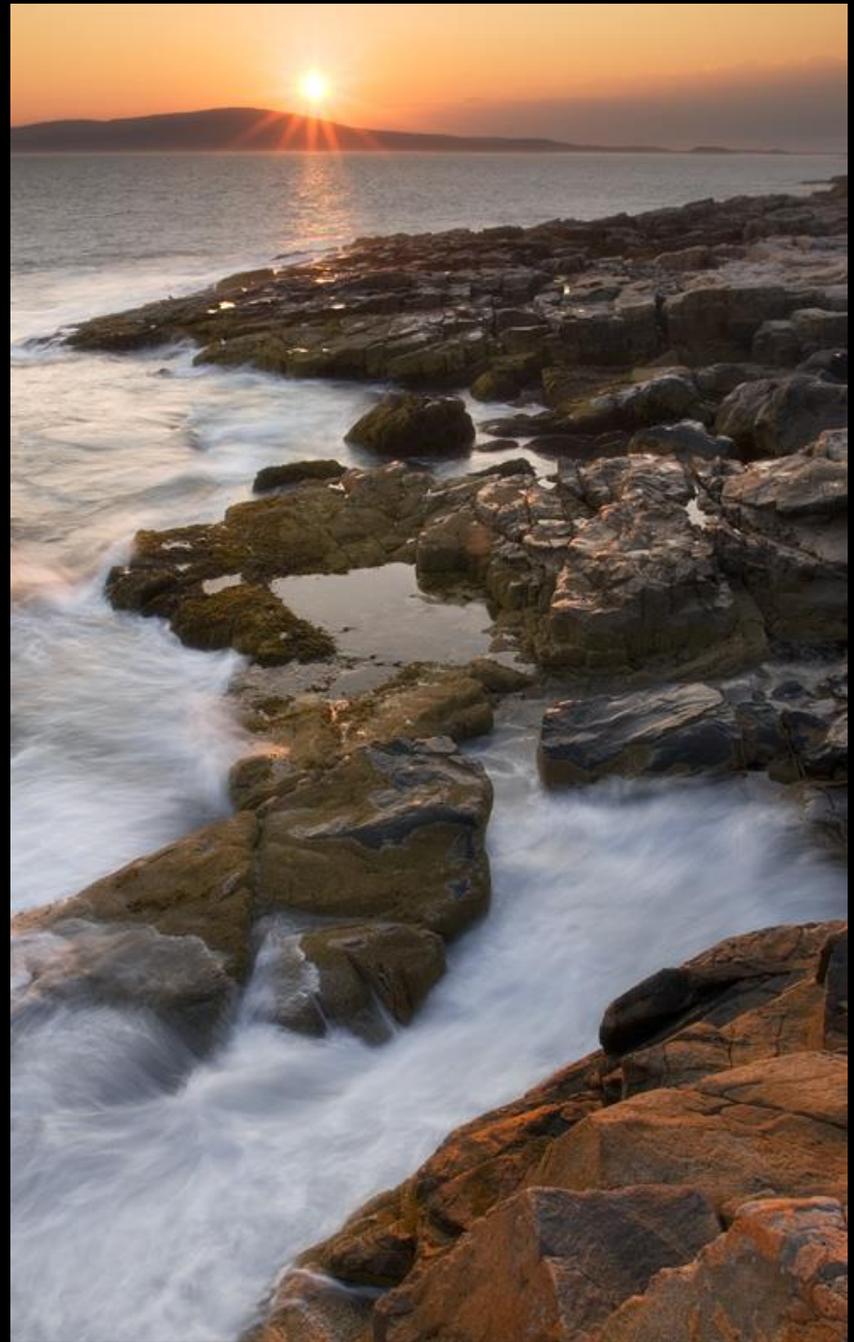


Temperature Anomaly (°F/°C)

CFSR 1979-2000 Baseline

World + 0.43 °C	Northern Hemisphere + 0.61 °C	North Atlantic + 0.19 °C
Equatorial Pacific + 0.81 °C	Southern Hemisphere + 0.31 °C	North Pacific + 0.79 °C

Future Implications for Maine?





MAINE'S CLIMATE FUTURE

ENTUBE
CFIWTLE
WVINE,2

2015
UPDATE

Maine's Average Annual Temperature

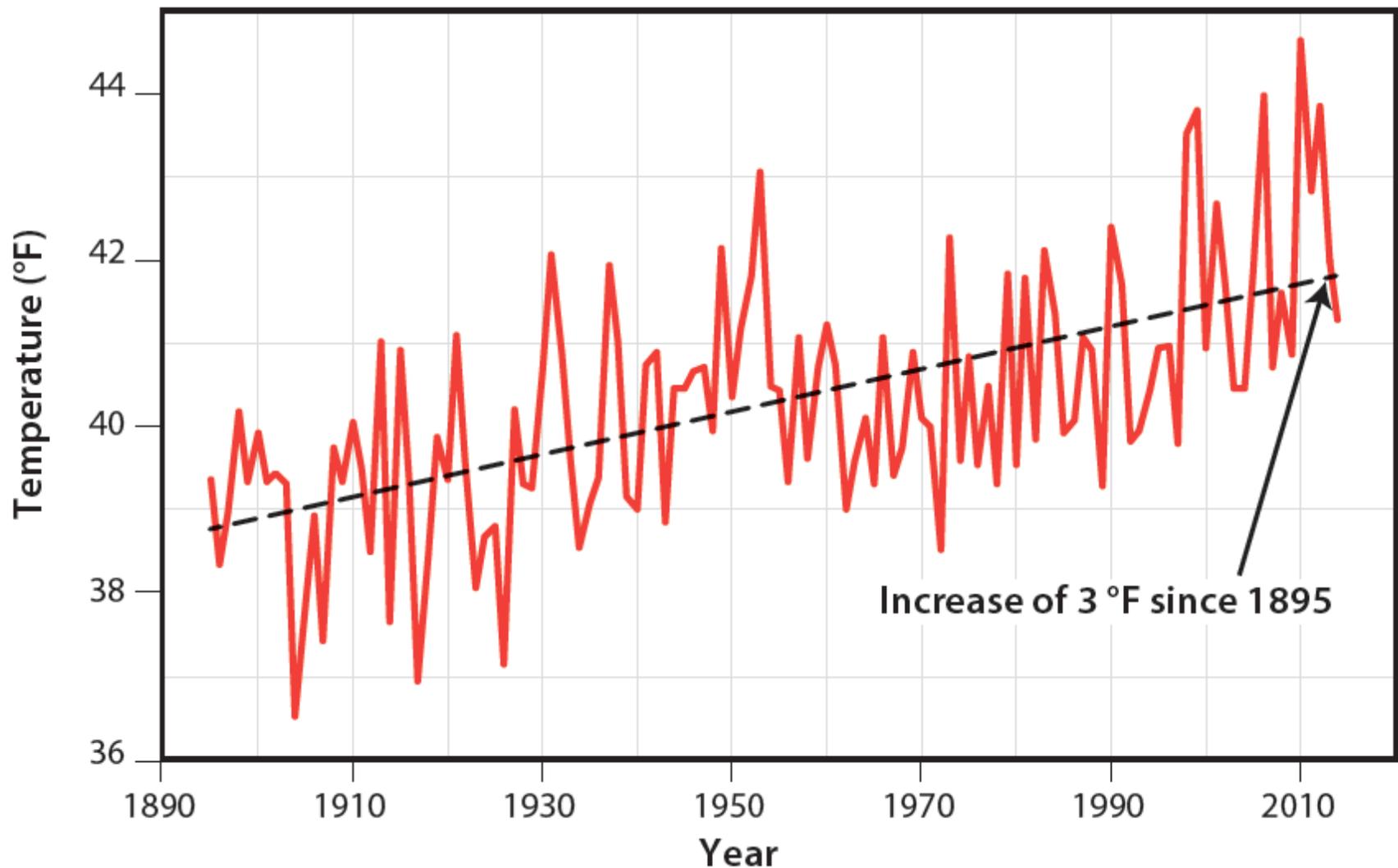


Figure 1. Mean annual temperature, 1895–2014, averaged across Maine from gridded monthly station records from the U.S. Climate Divisional Dataset (ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php). A simplified linear trend (black line) indicates that temperature increased 3 °F over the record period.

Maine's Changing Seasons

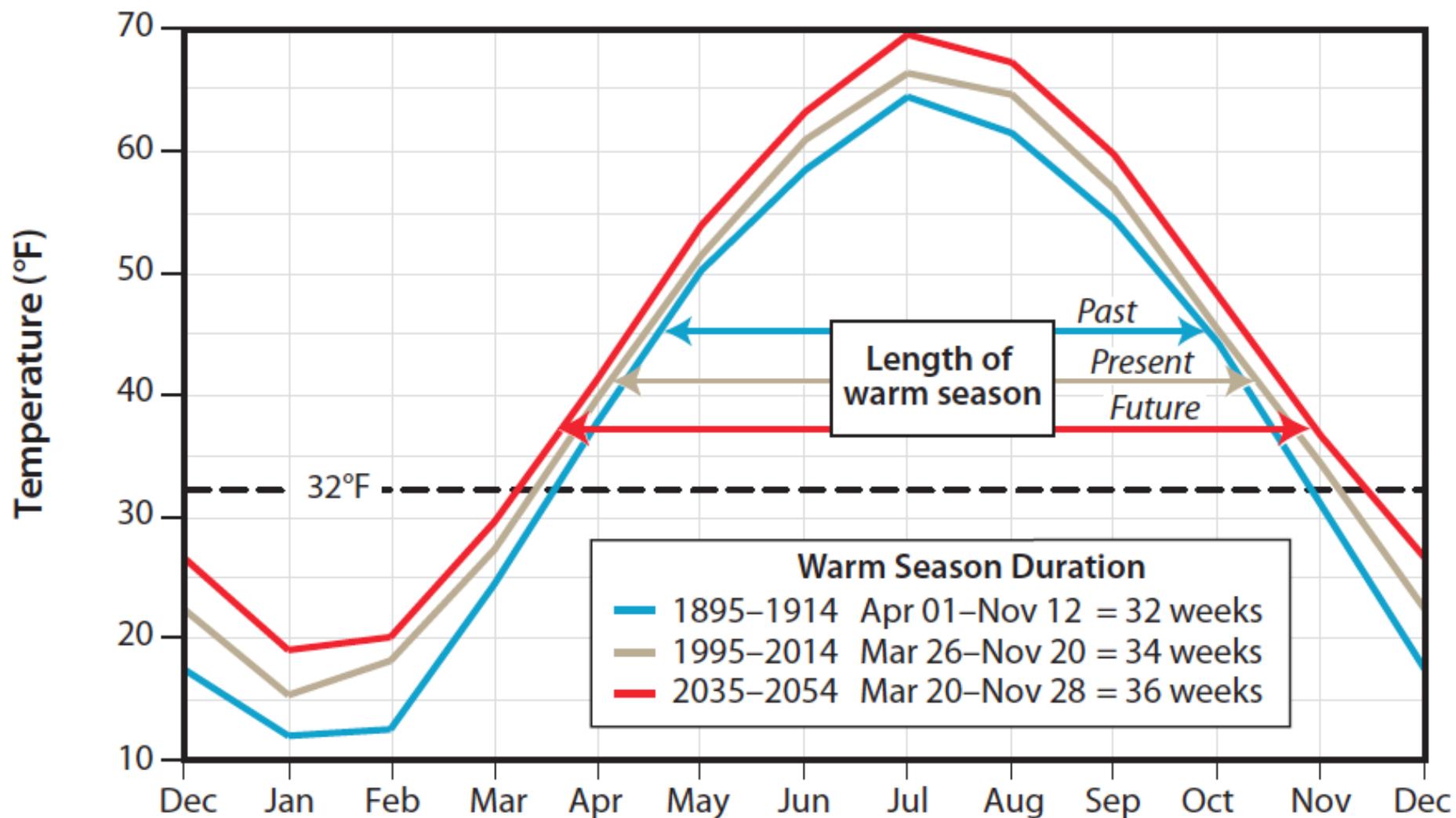


Figure 3. Mean monthly temperature averaged across Maine for historical (1895–1914), recent (1995–2014), and future (2035–2054) time periods. Historical and recent data from the U.S. Climate Divisional Dataset (ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php), and future prediction from an ensemble simulation of the IPCC emissions scenario A2.

Present and Future Temperature

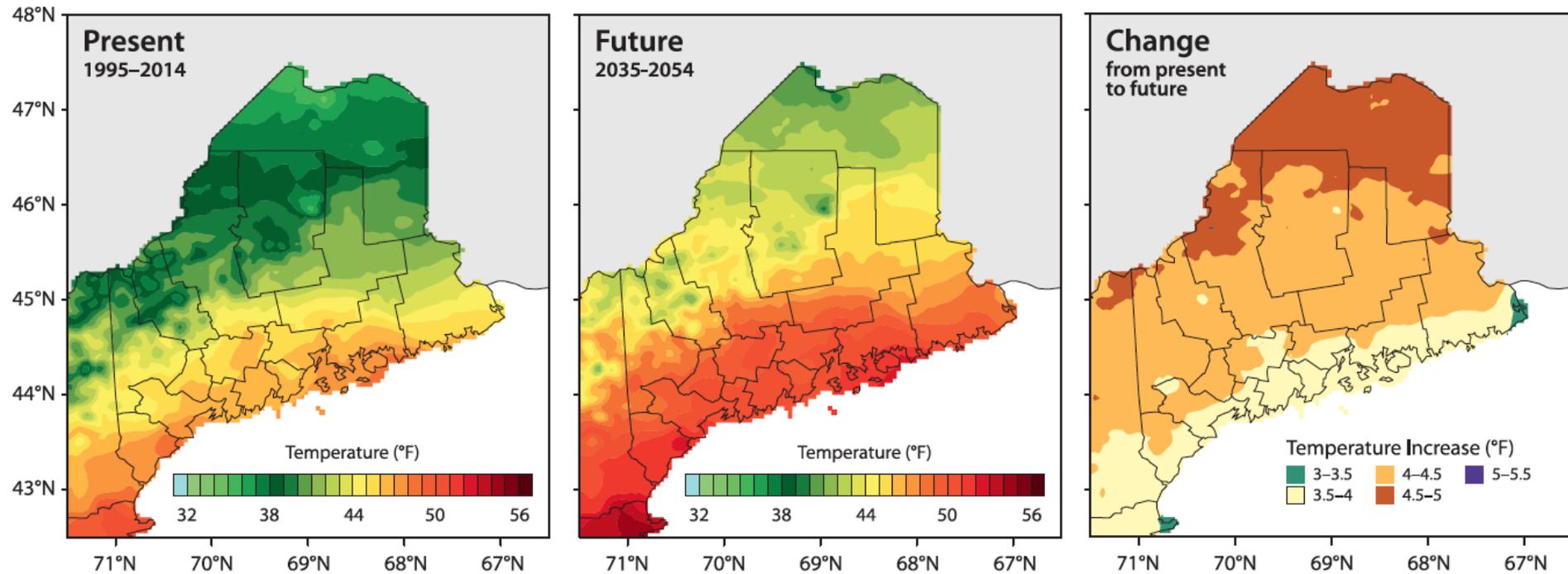


Figure 2. Maps showing mean annual temperature for 1995–2014 (left), 2035–2054 (center), and the predicted change or difference between the two time periods (right). The predicted rise in temperature by 2050 ranges 3.0–5.0 °F from the coast inland to the Canadian border. Maps derived from an ensemble simulation of the IPCC A2 emissions scenario.¹

More Hot Days

Number of Days
Heat Index $\geq 95^\circ\text{F}$

2000s \rightarrow 2050s

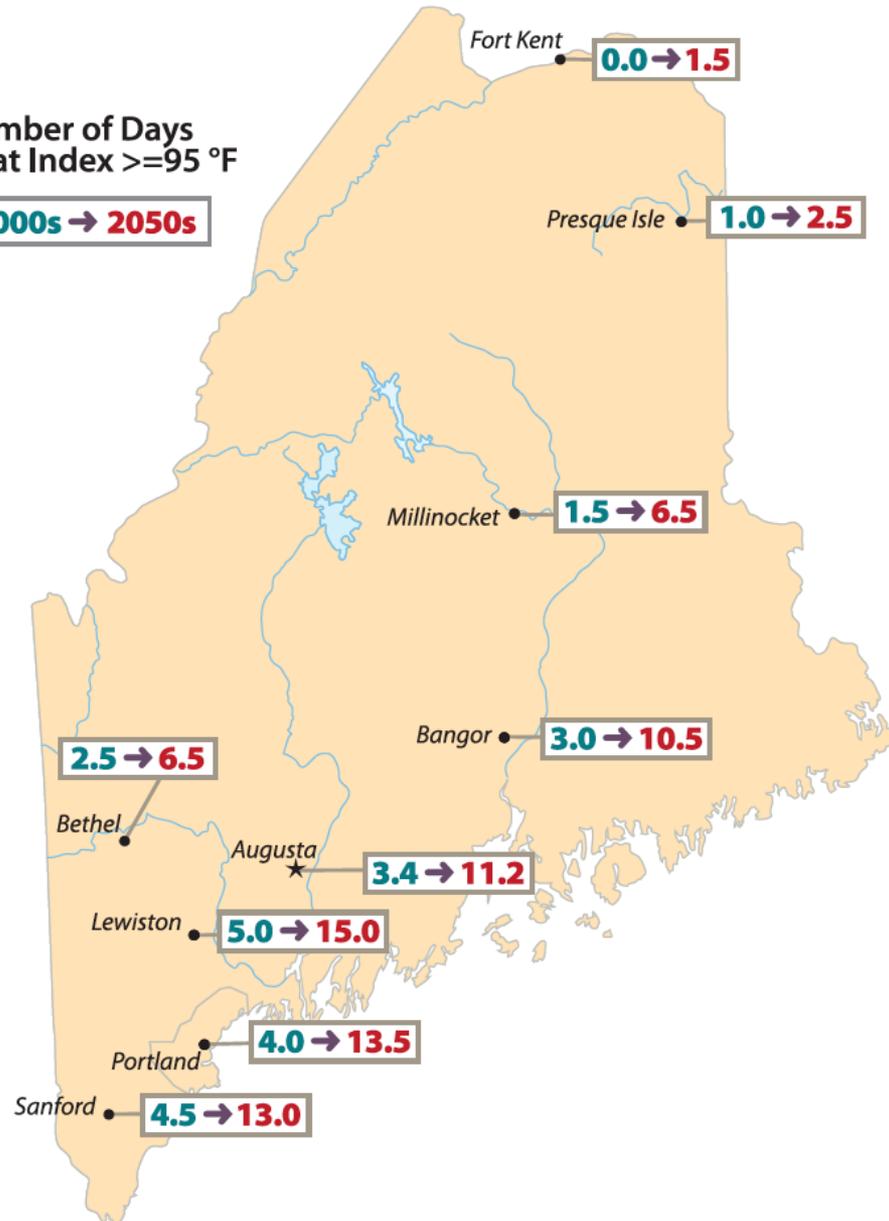


Figure 4. The average number of days when the heat index is greater than or equal to 95 °F at selected sites for 2000–2004 and 2050–2054. Predicted values derived from a 48-km downscale simulation of one ensemble member of the CCSM3 model for the IPCC A2 emissions scenario.

Maine's Total Annual Precipitation

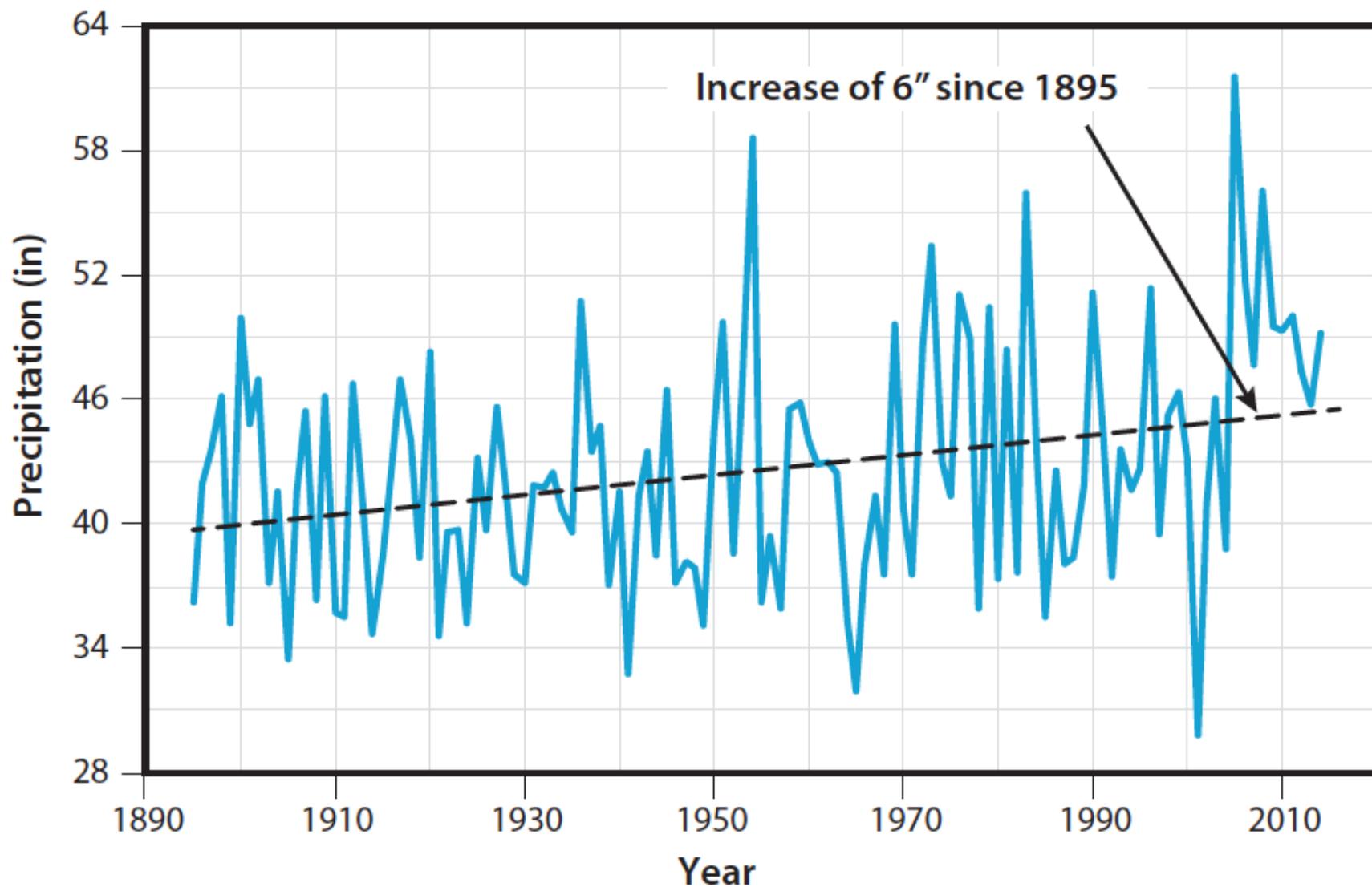
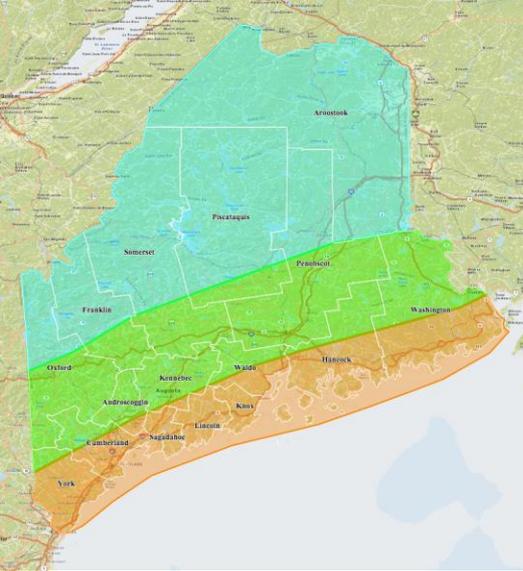


Figure 6. Total annual precipitation, 1895–2014, averaged across Maine from gridded monthly station records from the U.S. Climate Divisional Dataset (ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php). A simplified linear trend (black line) indicates that precipitation increased six inches,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

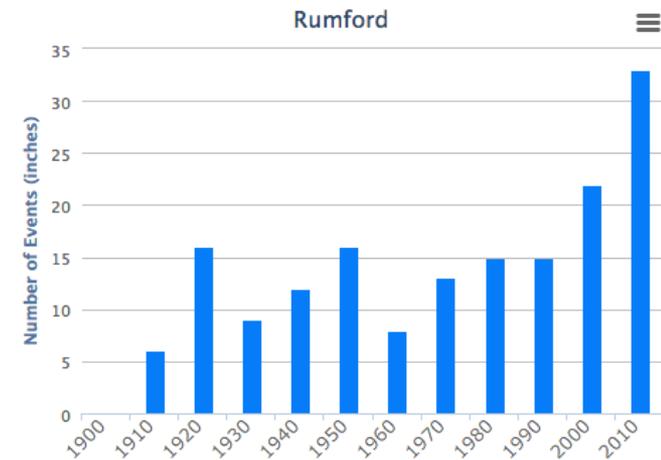
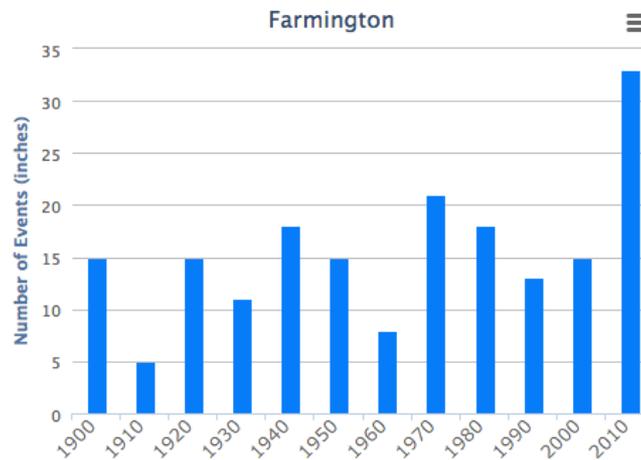
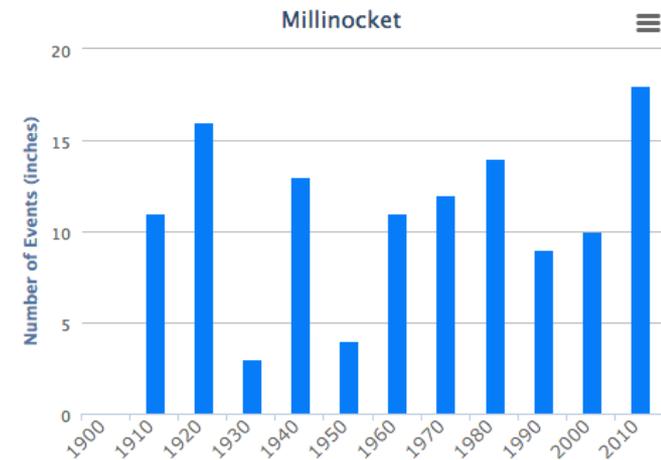
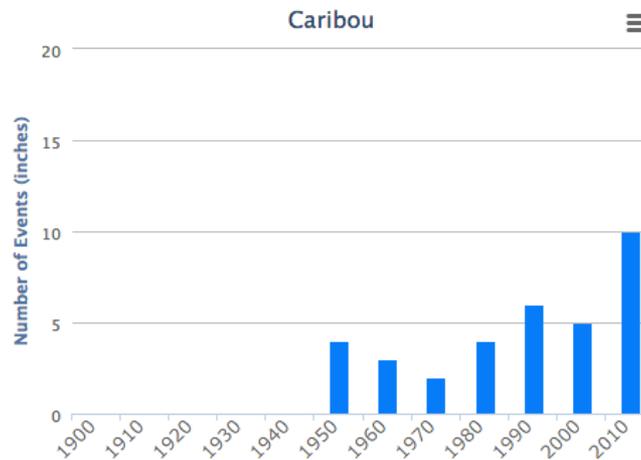
Extreme precipitation analysis for the 2015 Maine Climate Future Update report

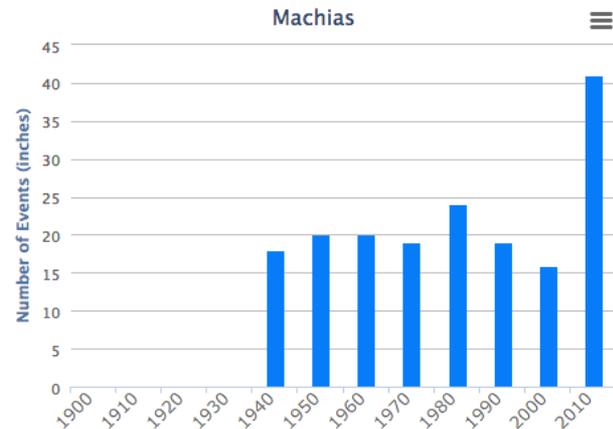
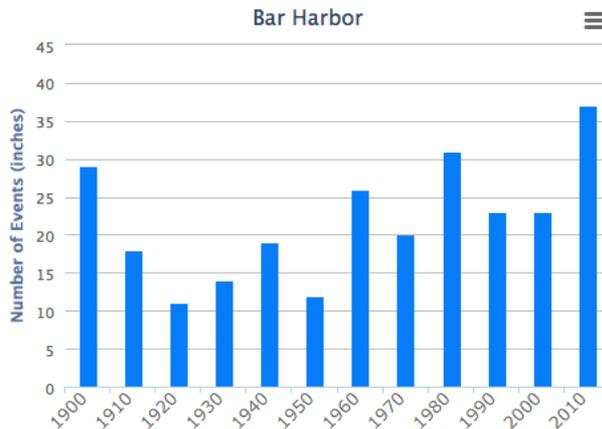
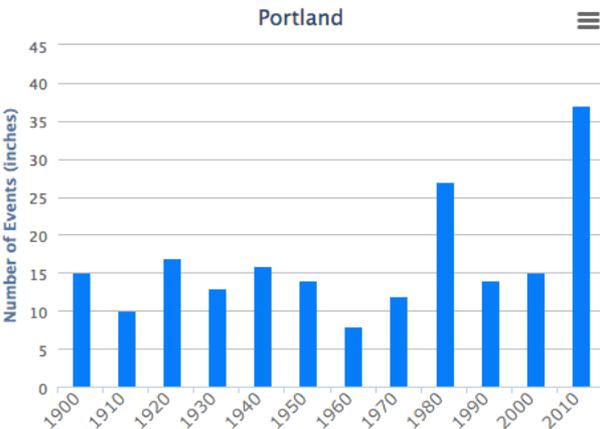
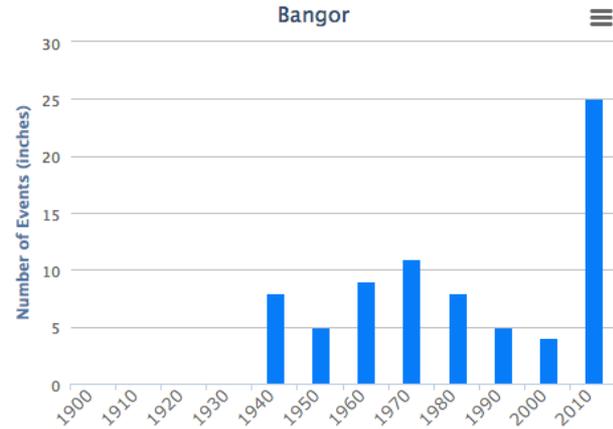
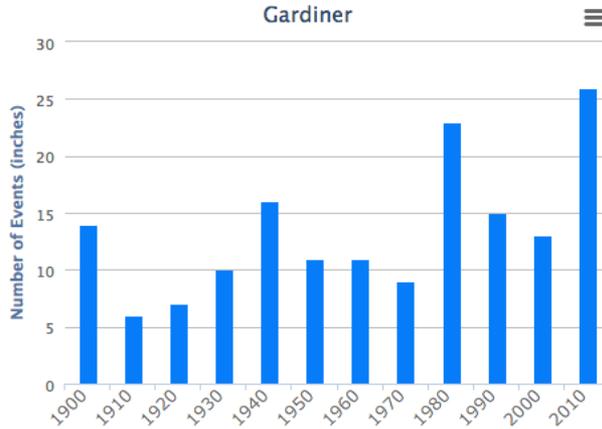
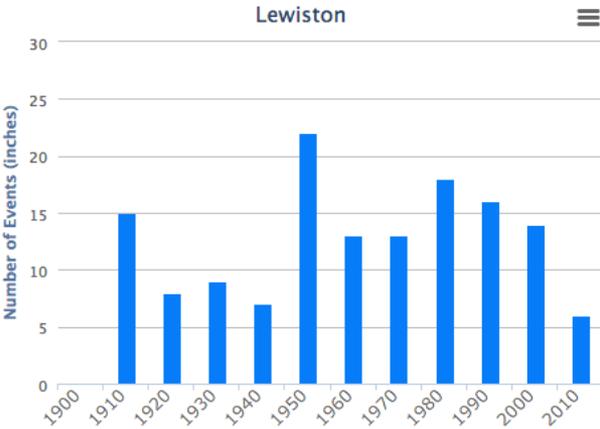
With Ivan Fernandez, Catherine Schmidt; and help from Jeff Auger



Number of 2-
inch per day
precipitation
events

GHCN data





Maine's Total Annual Snowfall

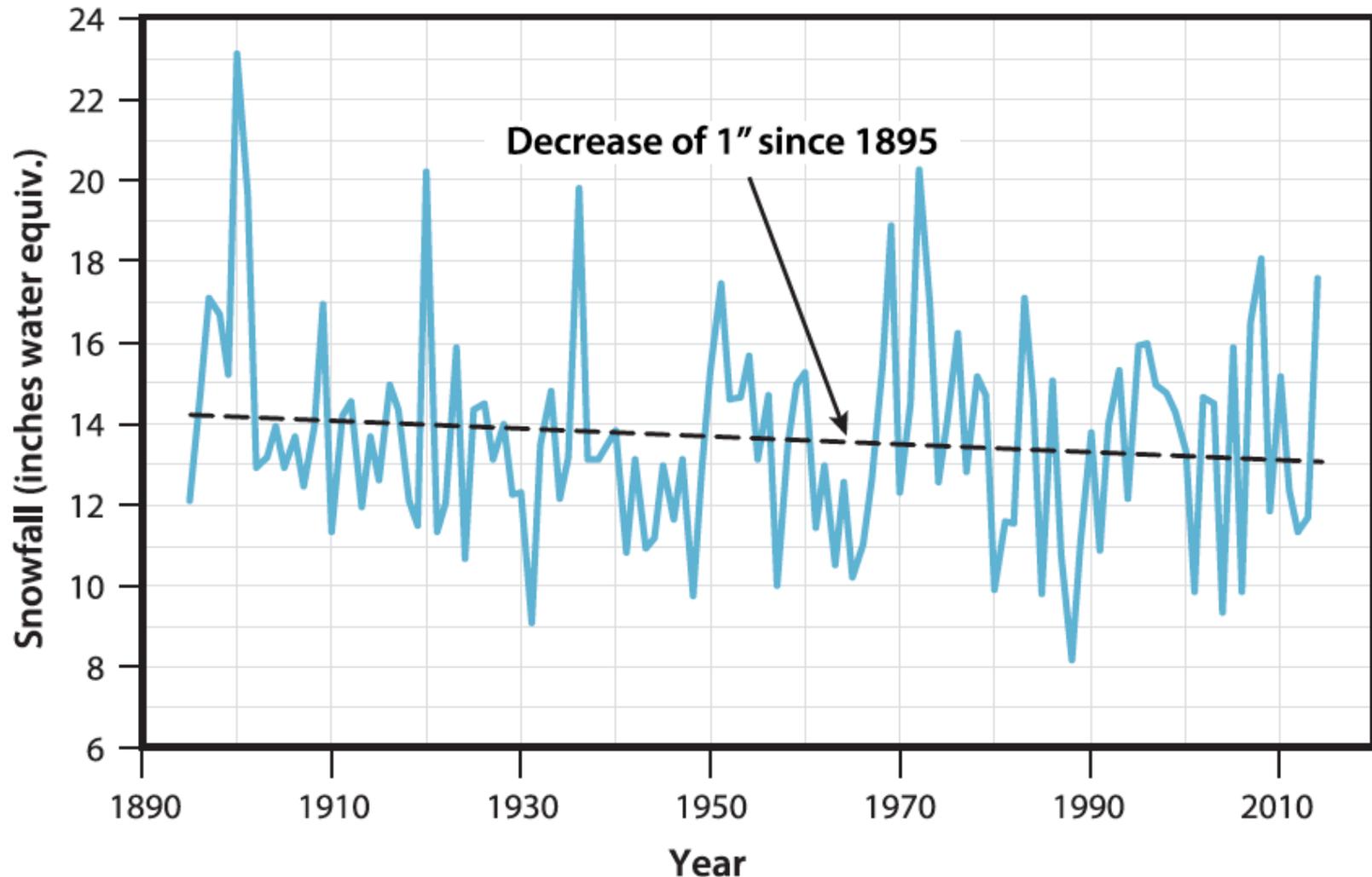


Figure 9. Total annual snowfall, 1895–2014, averaged across Maine, derived from gridded monthly temperature and precipitation station records from the U.S. Climate Divisional Dataset (ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php). A simplified linear trend (black line) indicates that snowfall decreased approximately 1.0 inches (6.6%) during the recording period.

Projected Snowfall Decline

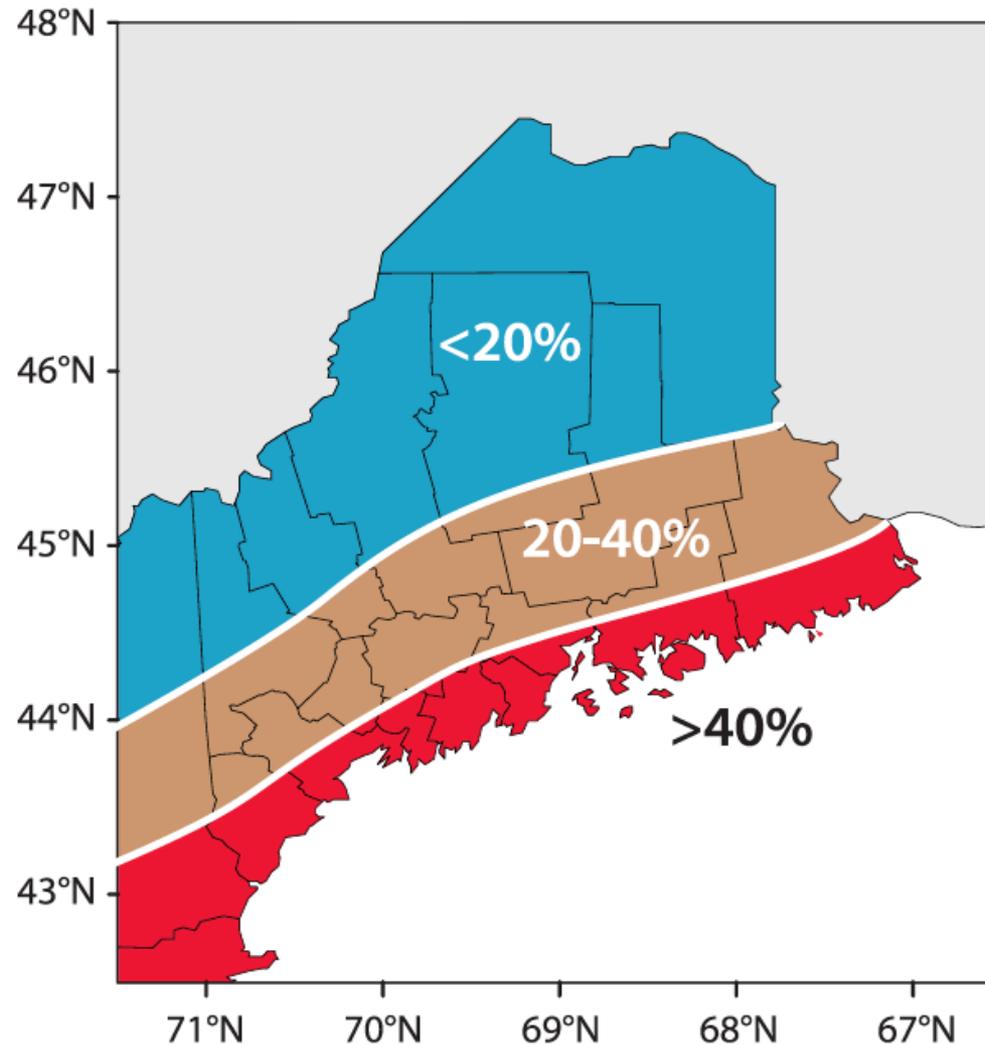


Figure 10. Map showing the predicted change or difference in total accumulated winter snow by climate zone from 1995–2014 to 2035–2054. The greatest changes are predicted to be along the coast, where many winters of the future will bring rain instead of snow. Map derived from an ensemble simulation of the IPCC A2 emissions scenario.

Sea Level Trend at Portland, Maine

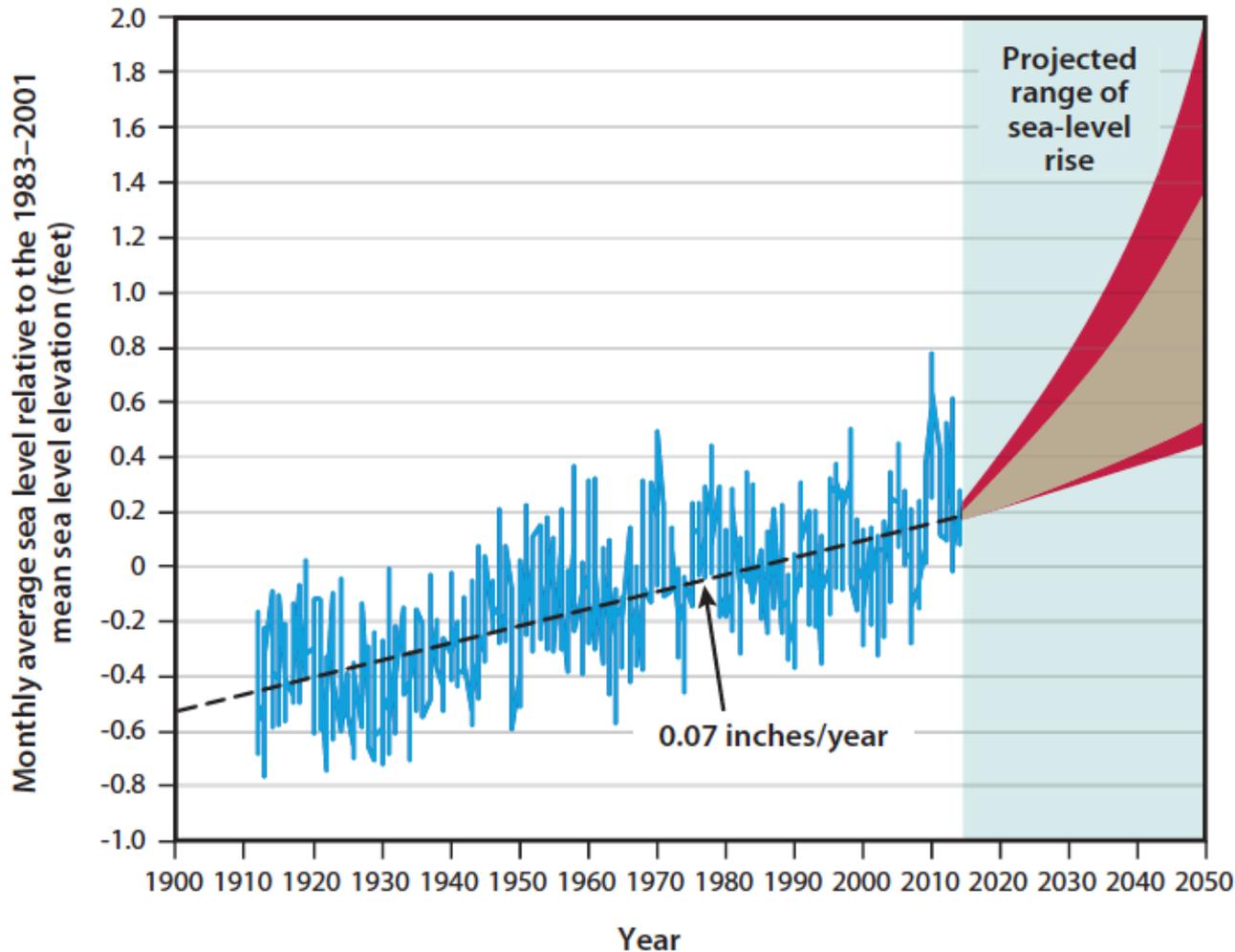
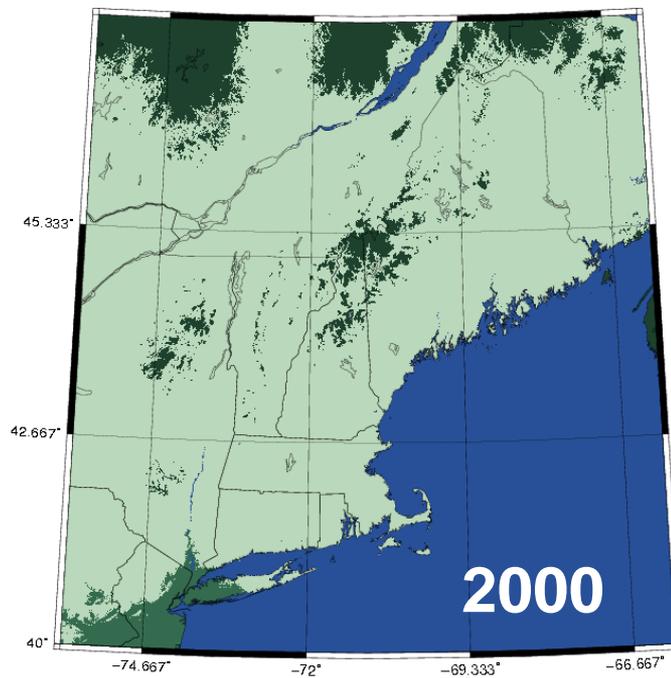
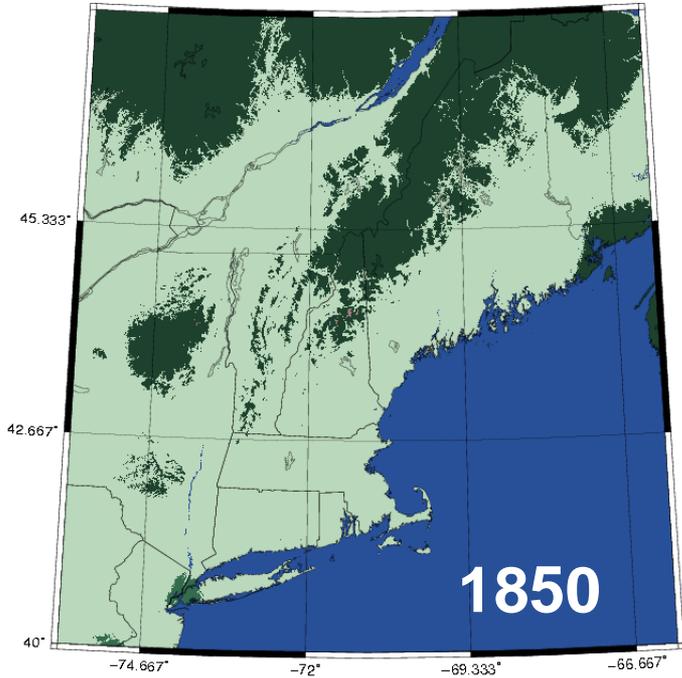
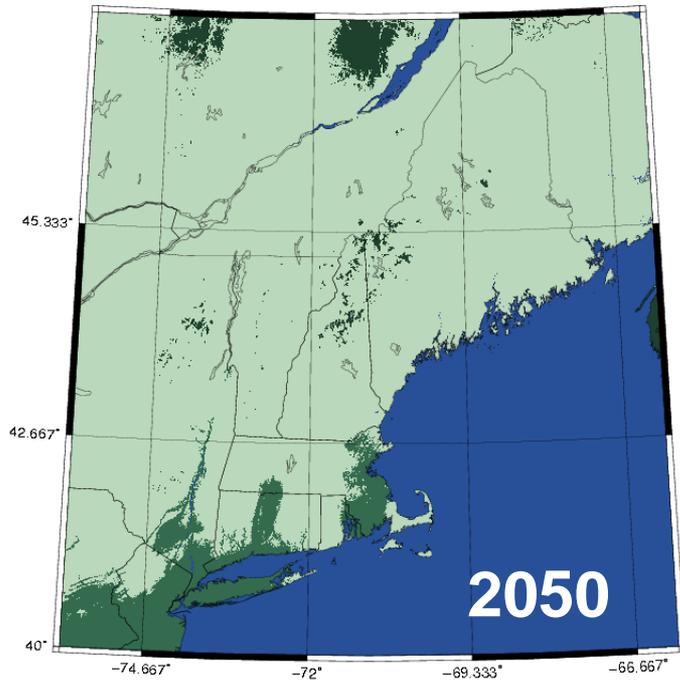


Figure 14. Sea level at Portland provided by the National Oceanic and Atmospheric Administration Center for Operational Oceanographic Products and Services (tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8418150). The mean sea level trend is 0.07 inches per year (1.9 mm/year) with a 95% confidence interval of ± 0.006 in/yr (0.16 mm/yr) based on monthly mean sea level data from 1912 to 2013, which is equivalent to a change of 0.62 feet in 100 years. The plotted values are relative to the most recent 19-year mean hourly sea level elevation established by NOAA (1983–2001).² Monthly sea level varies due to weather and the changing orbits of the earth and moon. The projected range of sea-level rise is from the latest National Climate Assessment and figure 2.26 therein from the NASA Jet Propulsion Laboratory.³ The projections reflect the range of possible scenarios based on other scientific studies. The currently projected range of sea-level rise of 0.5 to 2.0 feet by 2050 (1.0 to 4.0 feet by 2100) falls within a larger range that incorporates uncertainty about how glaciers and ice sheets will react to the warming ocean, the warming atmosphere, and changing winds and currents. The high end of these scenarios is provided for use by decision makers with a low tolerance for risk.



Boreal
 Mixed
Broadleaf

UNIVERSITY OF MAINE
 ENVIRONMENTAL CHANGE MODEL

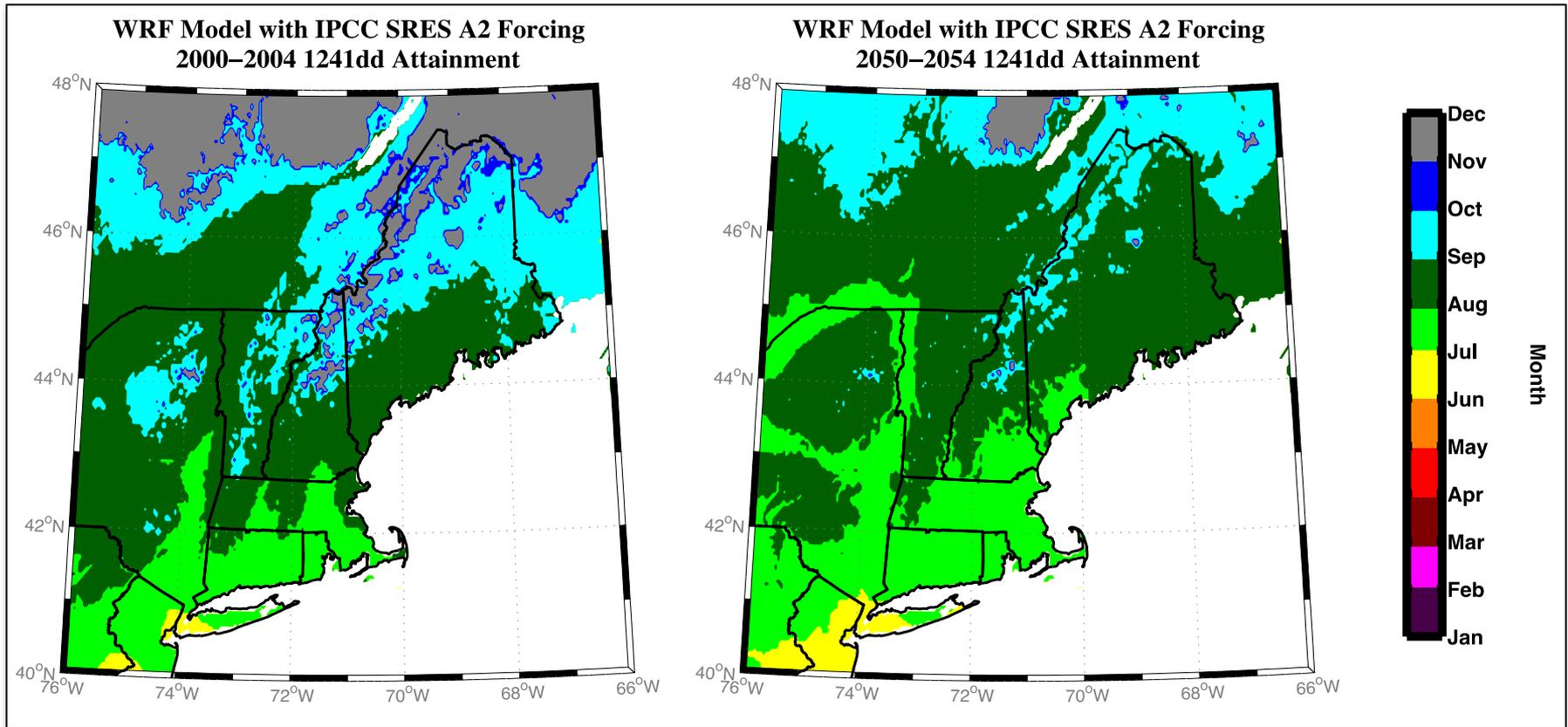


UNIVERSITY OF MAINE
 ENVIRONMENTAL CHANGE MODEL

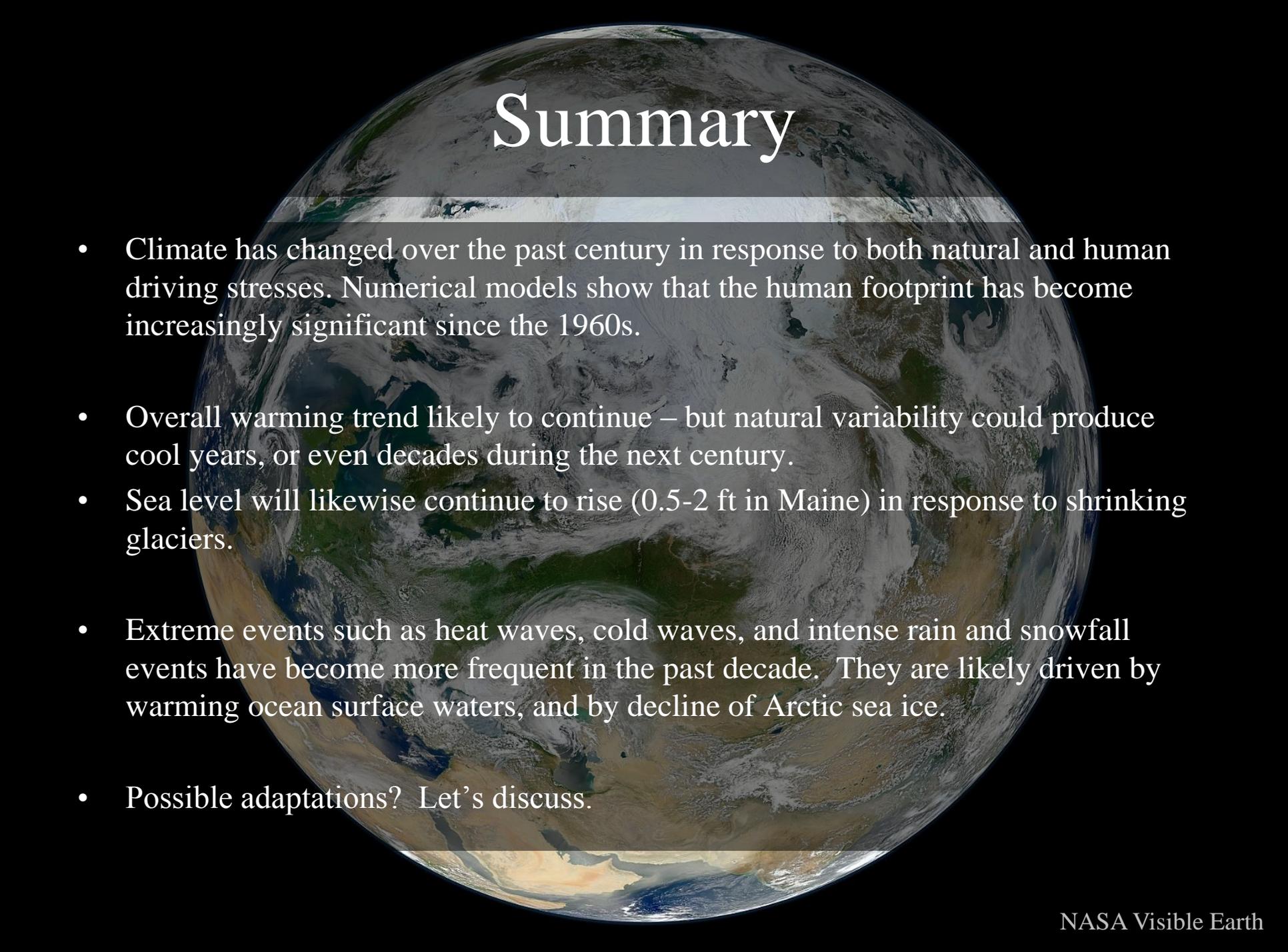
Forest Biomes are Migrating North

Potential Biomes from the UMaine
 Environmental Change Model

Future Spread of Lyme Tick: Sensitivity to Cumulative Degree Days



Larval emergence requires attainment of ~1240 degree days (6 ° C baseline). If this condition is met by the end of August (dark green on map above), then a tick is likely to survive and complete its life cycle. Otherwise, tick survival is unlikely (blue and gray on map above).



Summary

- Climate has changed over the past century in response to both natural and human driving stresses. Numerical models show that the human footprint has become increasingly significant since the 1960s.
- Overall warming trend likely to continue – but natural variability could produce cool years, or even decades during the next century.
- Sea level will likewise continue to rise (0.5-2 ft in Maine) in response to shrinking glaciers.
- Extreme events such as heat waves, cold waves, and intense rain and snowfall events have become more frequent in the past decade. They are likely driven by warming ocean surface waters, and by decline of Arctic sea ice.
- Possible adaptations? Let's discuss.

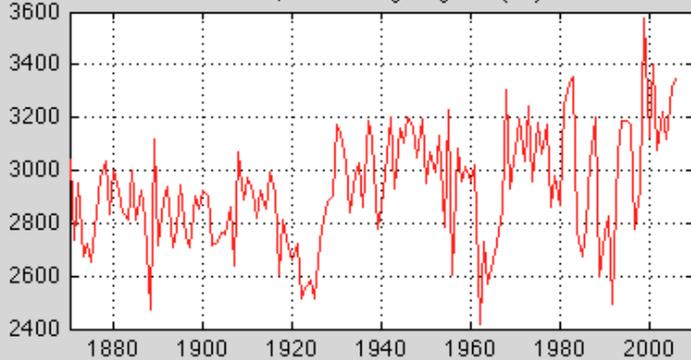


Thank You

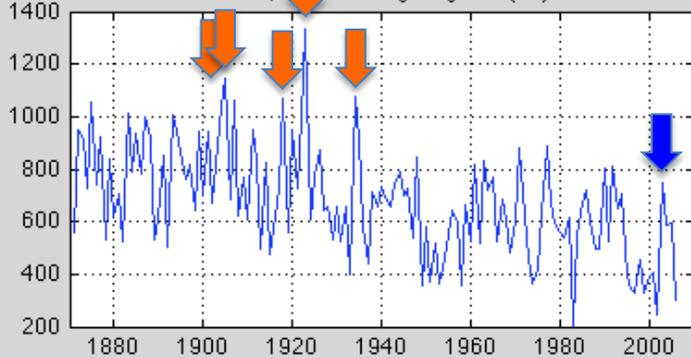
Funding Sources:
NSF, CSEF, Maine CDC, Climate Change Institute, University of Maine

Classic Maine Winters are History

Orono, ME Melting Degrees (°C)



Orono, ME Freezing Degrees (°C)



Carver's Harbor, Vinalhaven, Feb. 1918



Source: Penobscot Bay History Online

Penobscot Bay commonly froze over during 19th century winters, but only five times in the 20th century: 1904, 1905, 1918, 1923, and 1934.

Extreme Precipitation Events

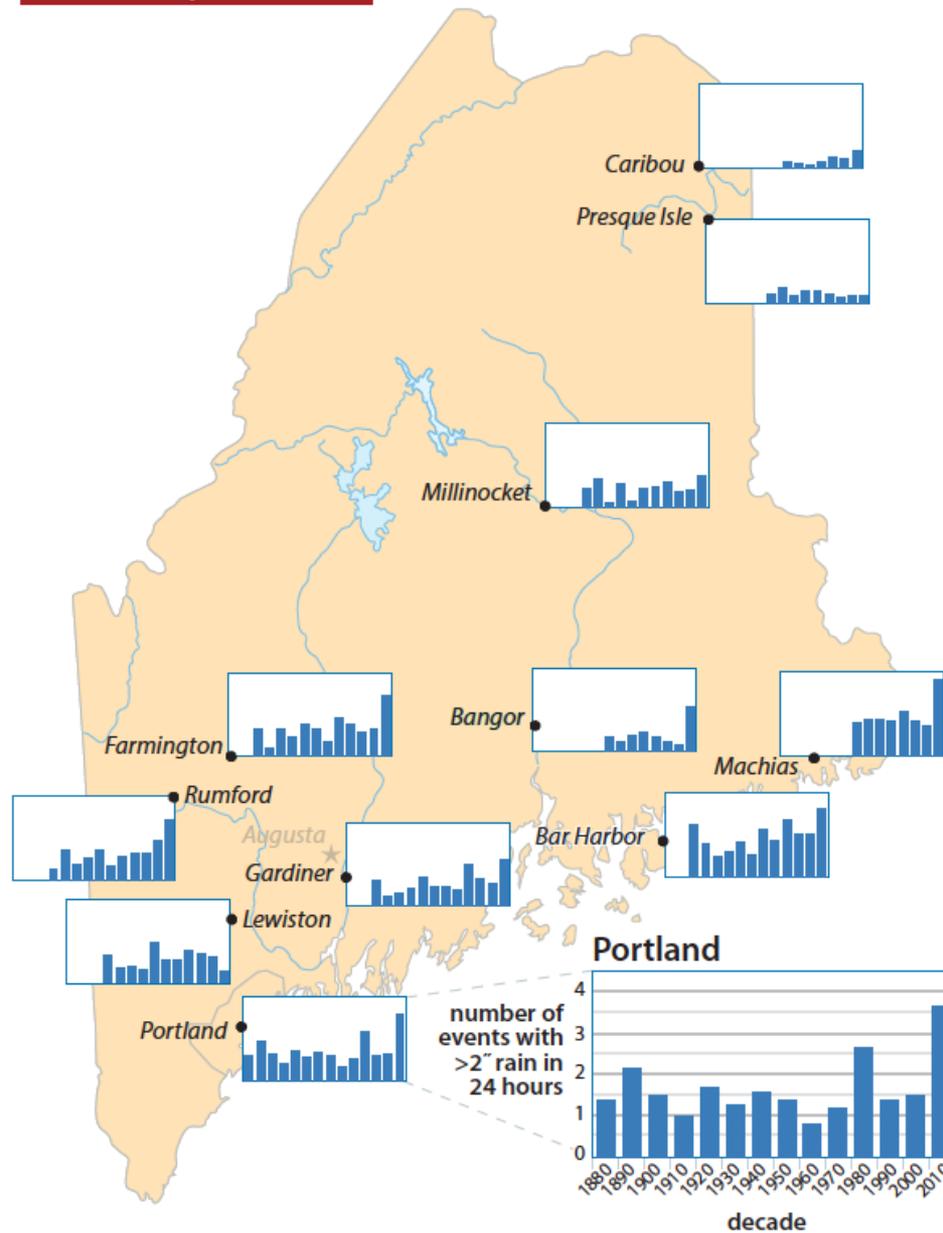
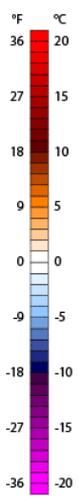
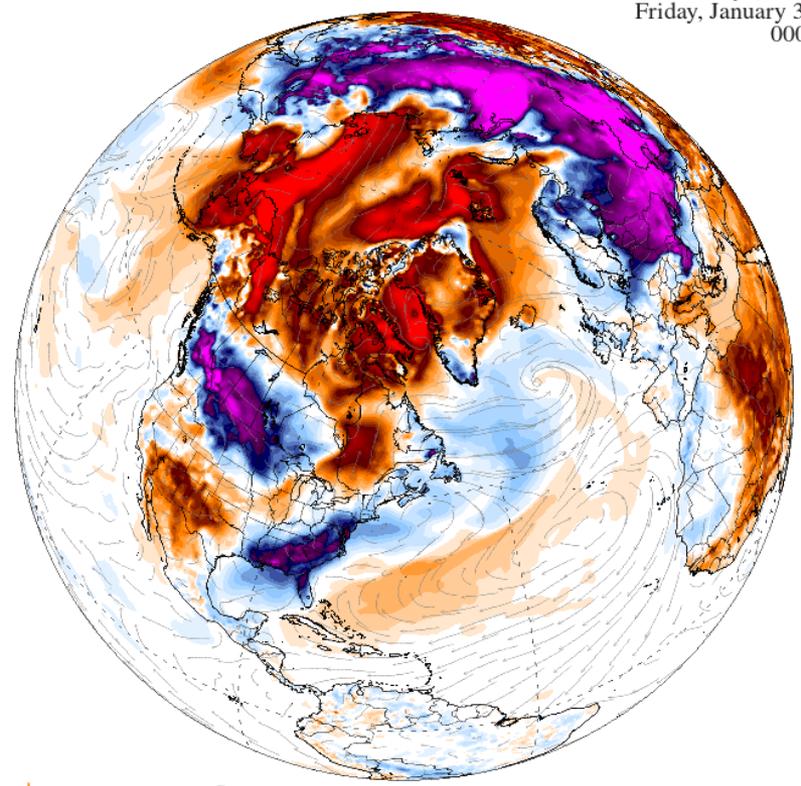
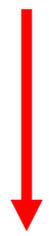


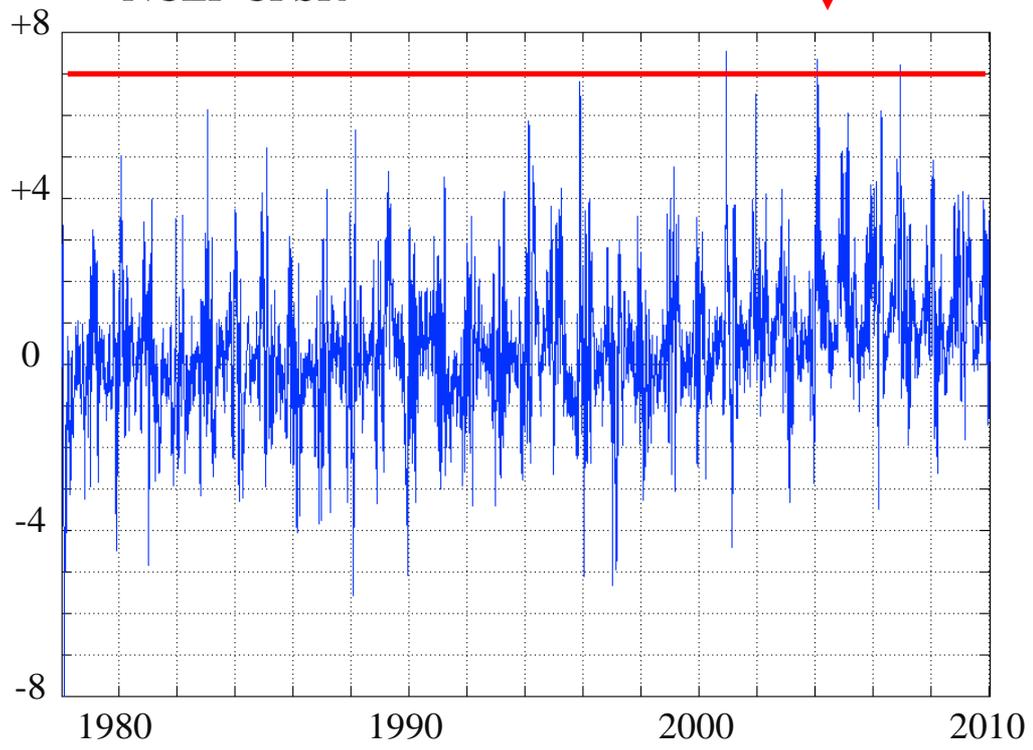
Figure 8. Extreme precipitation events recorded at 11 long-term meteorological stations across the state. Here, we use daily data from the Global Historical Climatology Network, and define an extreme event as two or more inches precipitation (rain or water equivalent snow) per 24-hour period. Bar plots show the average number of extreme events over 10-year intervals for each station. Nine out of 11 stations register the highest frequency of extreme events in the past ten years, with Bangor, Farmington, Machias, Portland, and Rumford showing the most distinct increases.



+7 ° C anomaly appears in
1979-present reanalysis only 4
times; all events after year 2000



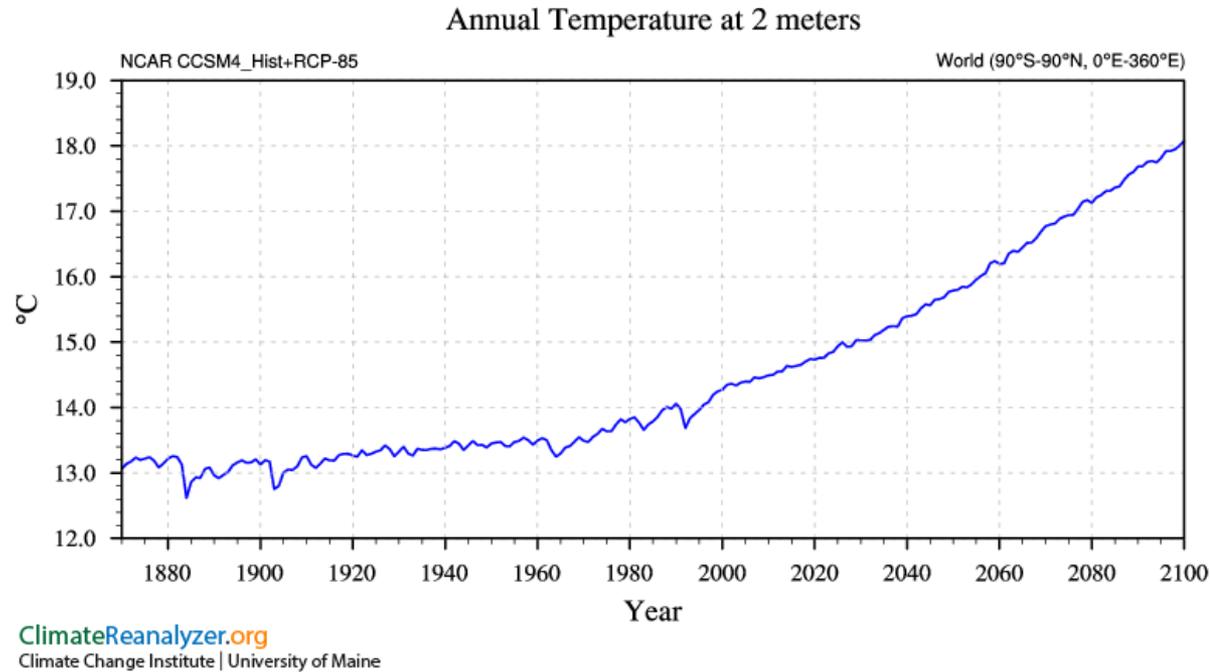
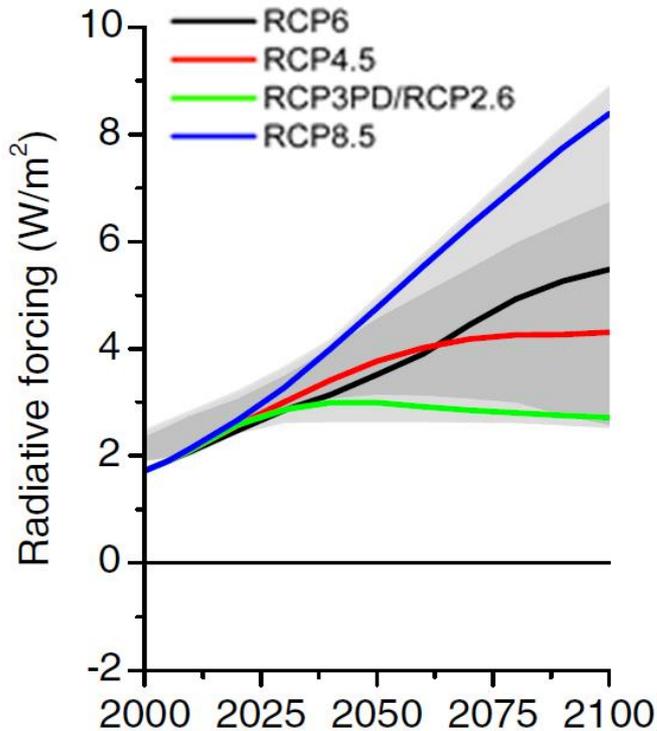
Arctic 2-m Temperature Anomaly
NCEP CFSR



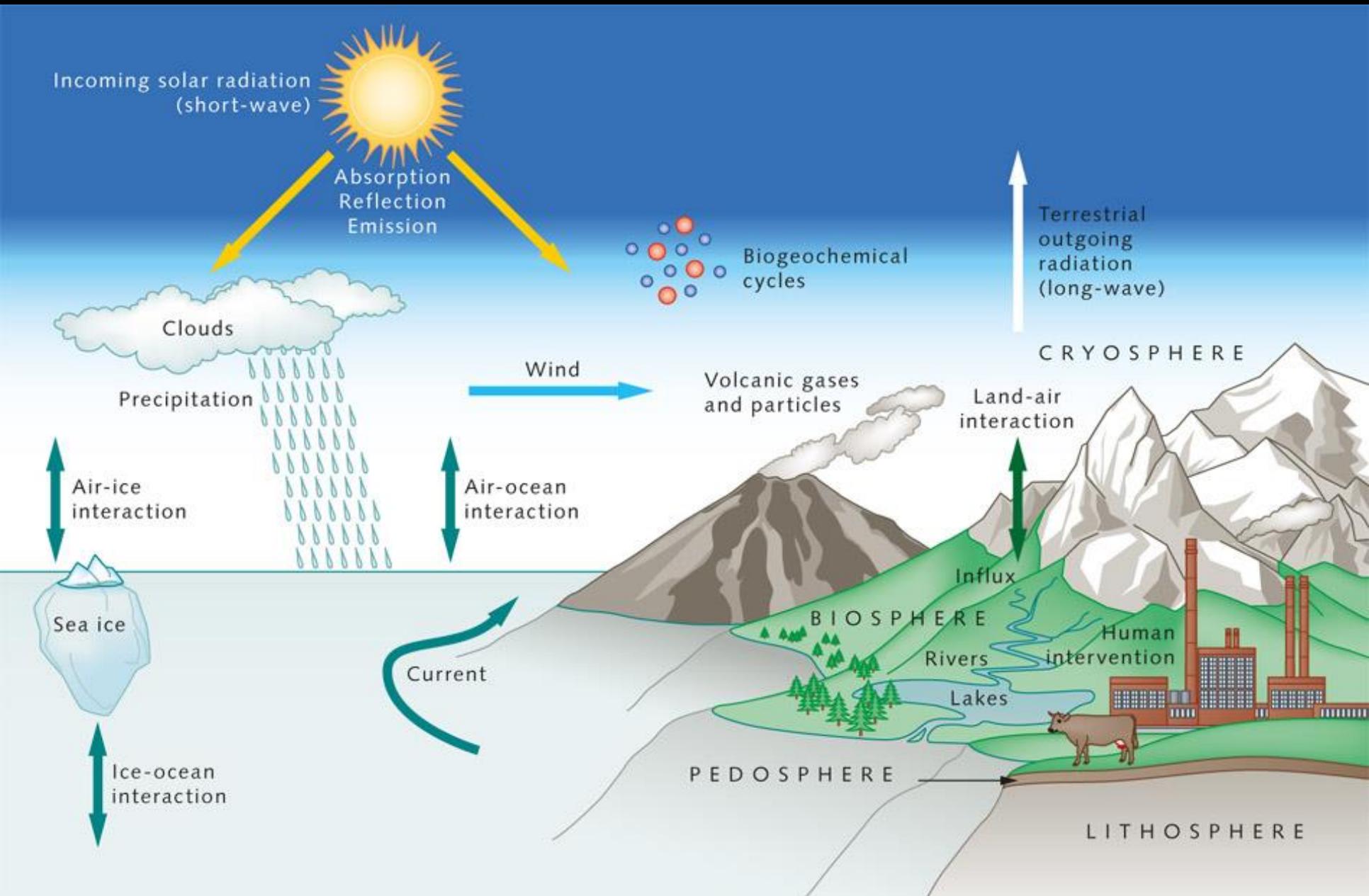
The Climate Reanalyzer™ | cci-reanalyzer.org

World	Northern Hemisphere	Arctic
+ 0.43 °C	+ 0.79 °C	+ 6.50 °C
Tropics	Southern Hemisphere	Antarctic
+ 0.55 °C	+ 0.08 °C	+ 0.52 °C

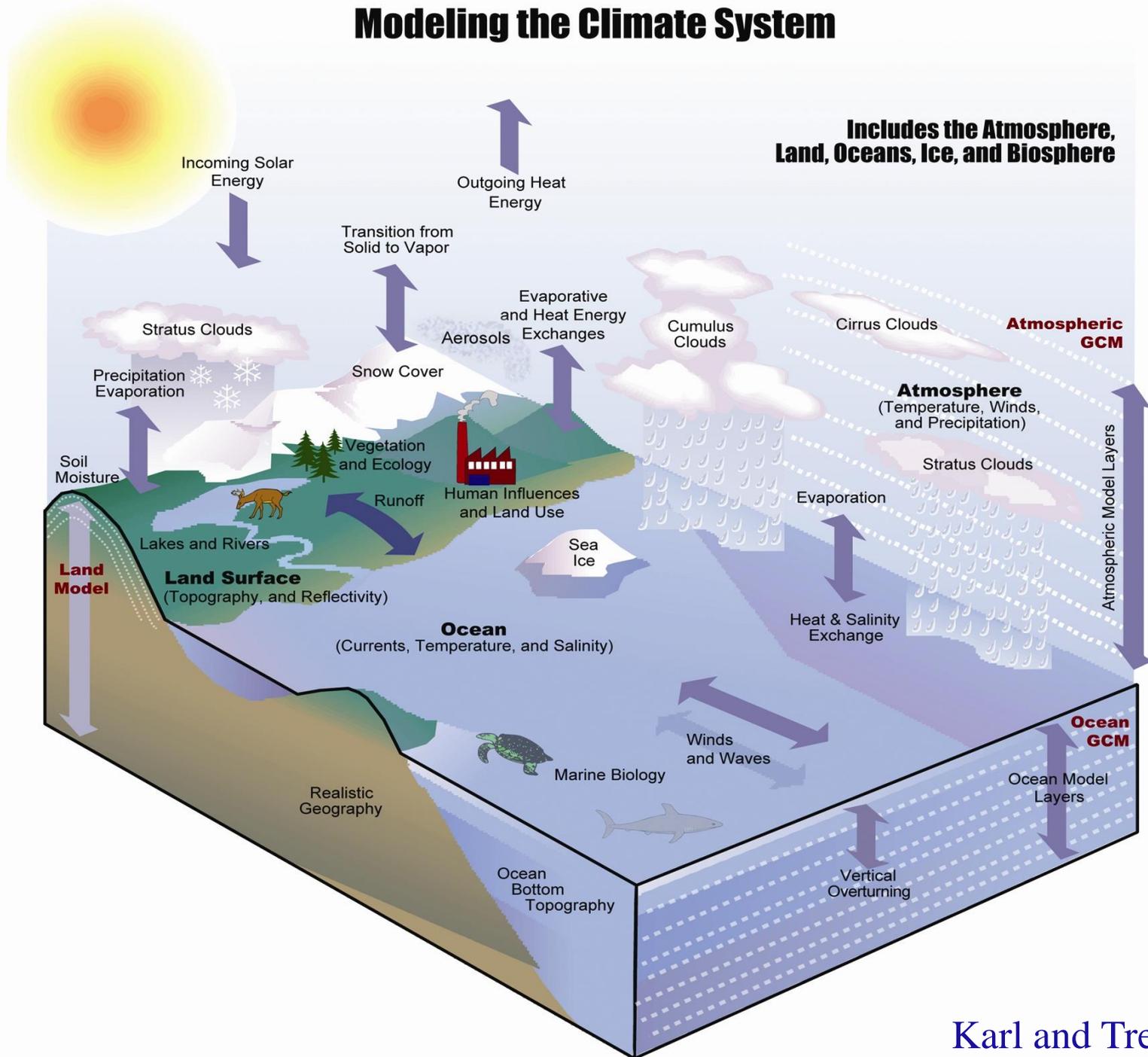
IPCC AR5 Representative Concentration Pathways (RCPs)



ClimateReanalyzer.org
Climate Change Institute | University of Maine



Modeling the Climate System



Model Discretization and Spatial Resolution

The governing partial differential equations are discretized using about 20-30 vertical layers, and a horizontal grid typically 2.8° latitude (300 km) (T42 spherical harmonic spectral depiction) or 1.4° latitude (150 km) (T85).

