Climate Change and New Hampshire's Waters & Loons

Dr. Elizabeth Burakowski, UNH-Durham

Canoeing with a loon
Umbagog (2011)

New Hampshire Lakes 2019 Lakes Congress
Merrimack River Watershed Council, Parker River Wildlife Refuge

University of New Hampshire

Dr. Elizabeth Burakowski, Research Assistant Professor

- Climate and Land Modeling
- Satellites
- Community Science
- K-12 Teacher and Student Education
- Advocacy and Activism

Volume I Released Nov. 2017

Assessment of the physical science

science2017.globalchange.gov

“Global annually averaged surface air temperature has increased by about **1.8ºF** over the last 115 years. This period is now the **warmest** in the history of modern civilization.”

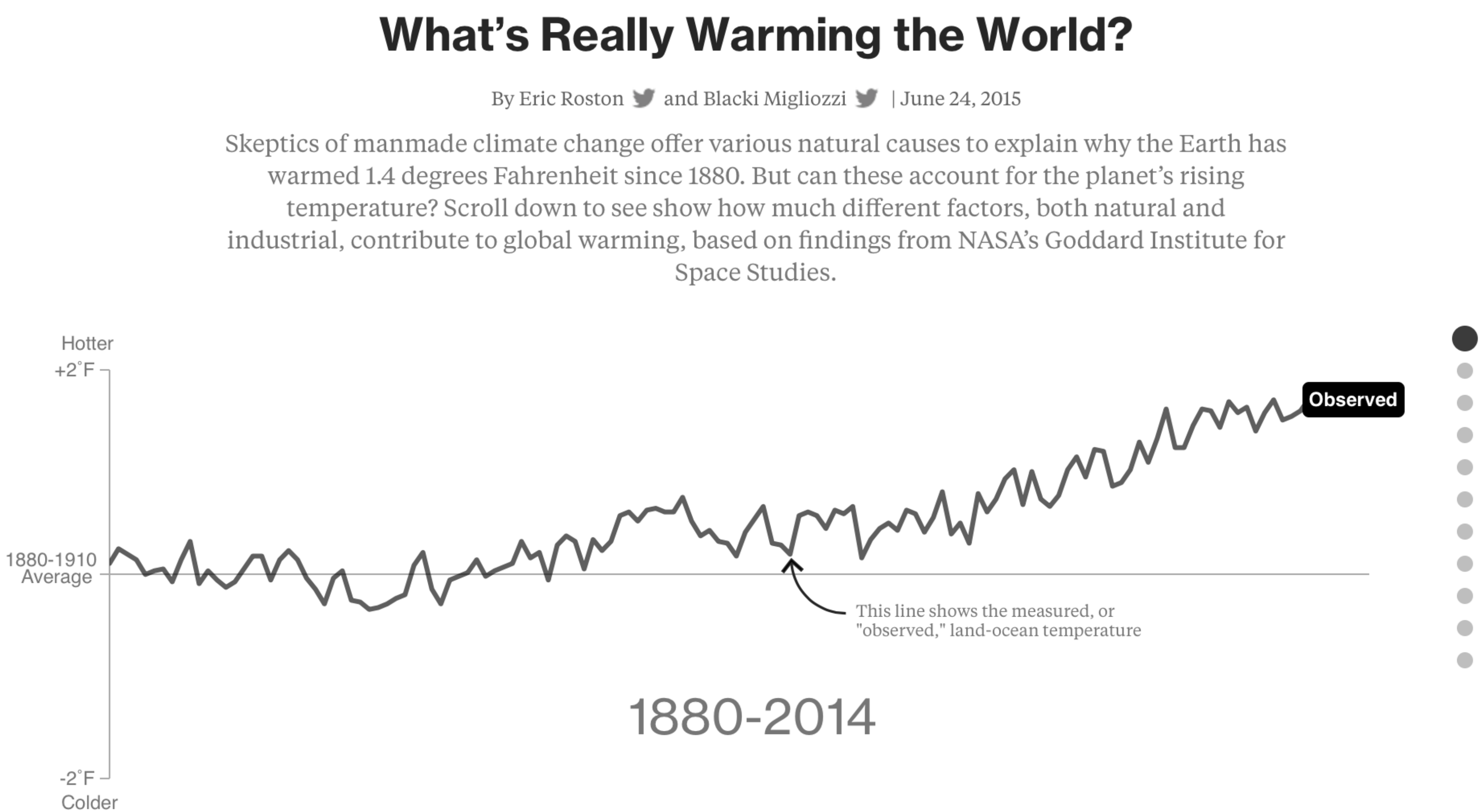
Earth’s temperature, 1880-2018

NASA Scientific Visualization Studio

Climate vs. Weather

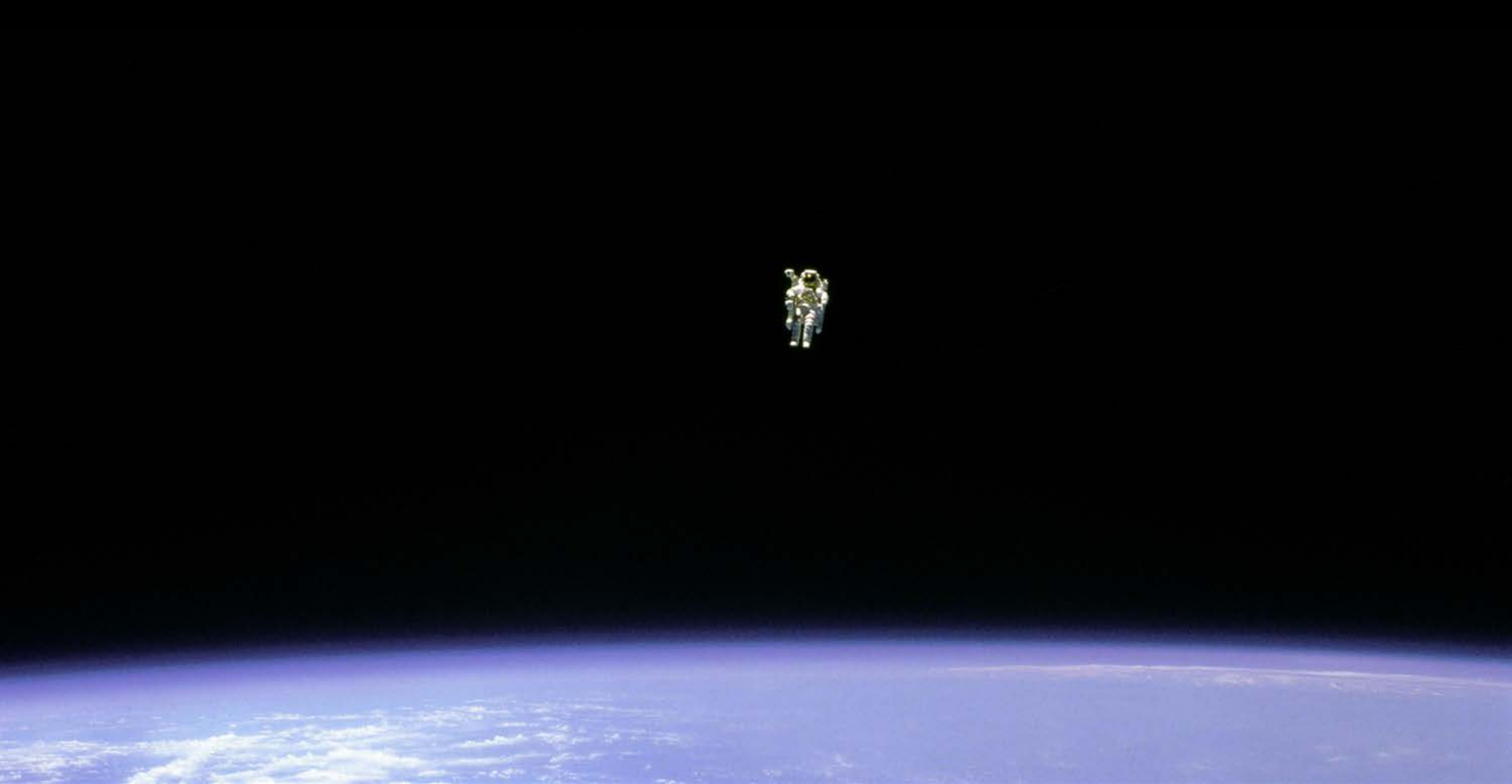
"…it is extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century."

How we know it's humans.



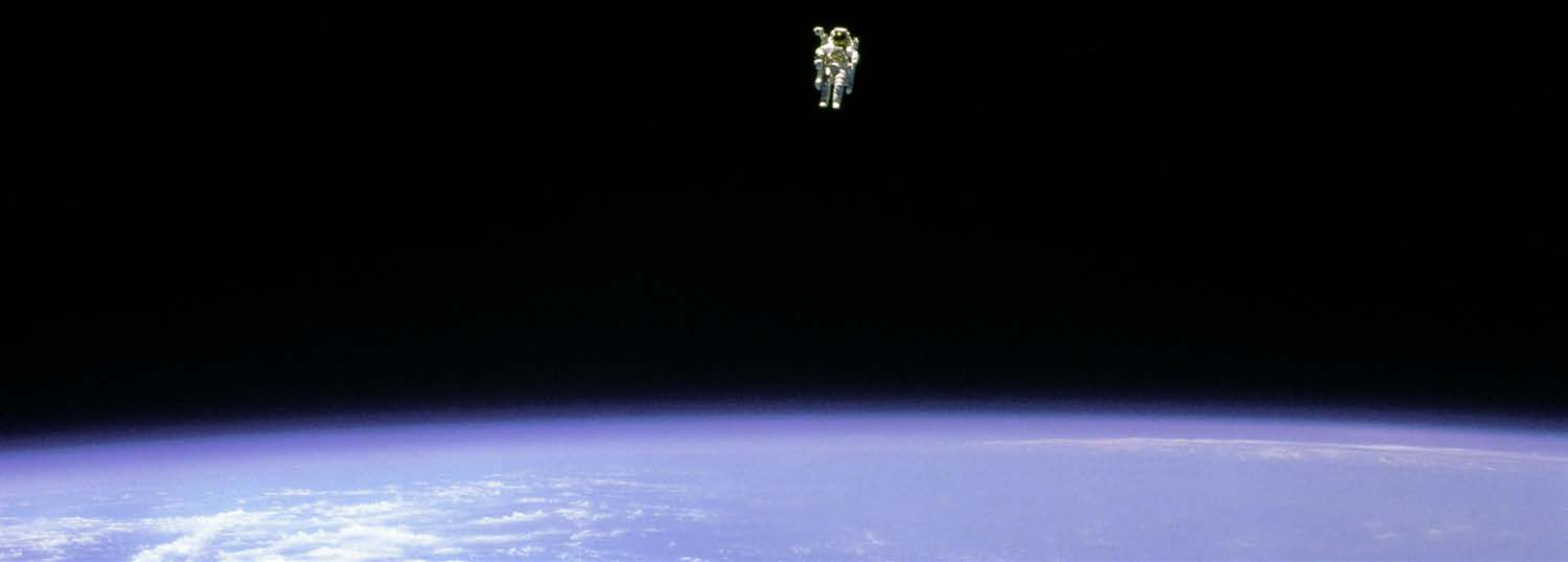
From: https://www.bloomberg.com/graphics/2015-whats-warming-the-

Welcome to the Anthropocene

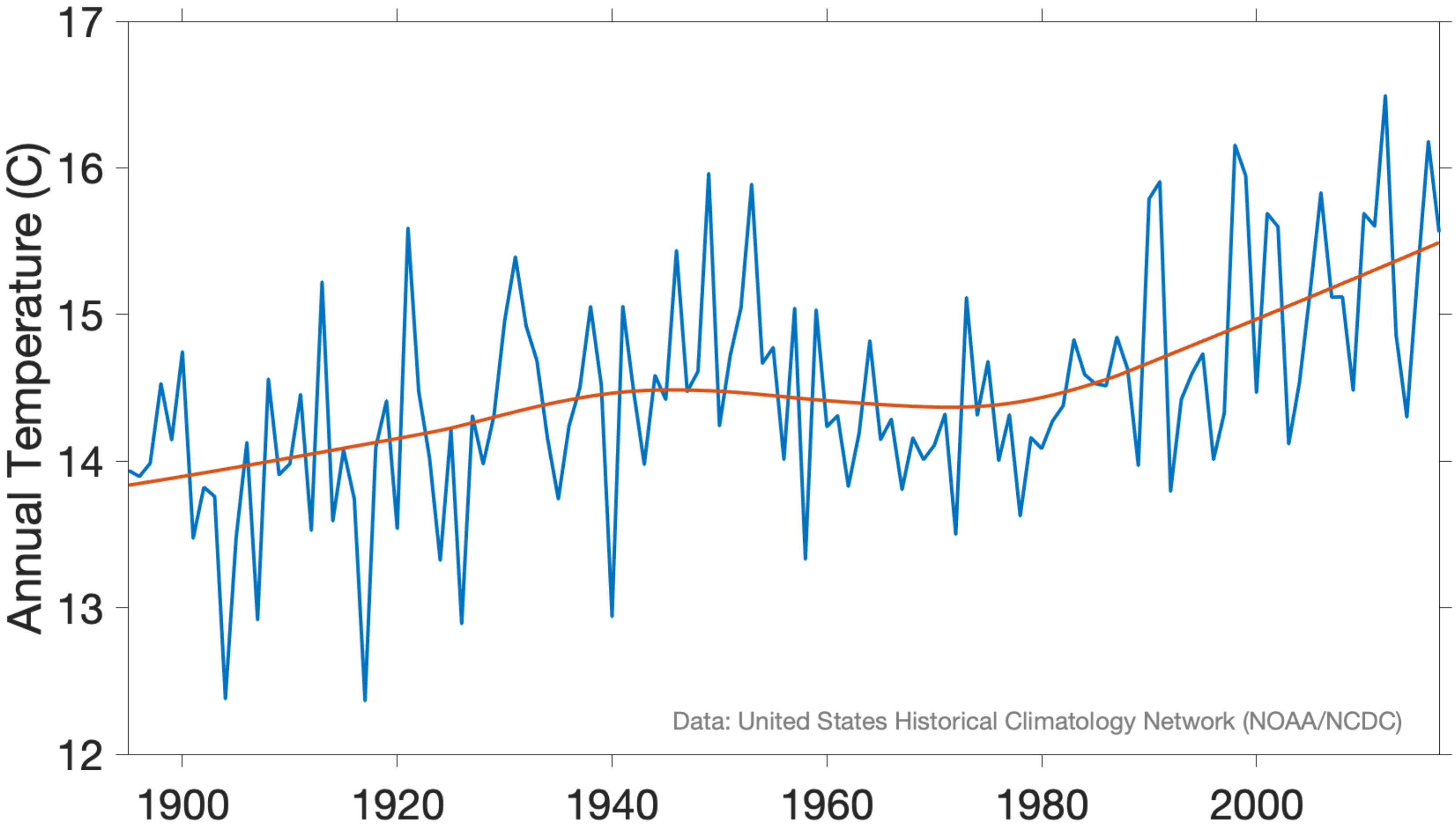


Welcome to the Anthropocene

n. the current geologic period during which human activity has been the dominant influence on climate and the environment.

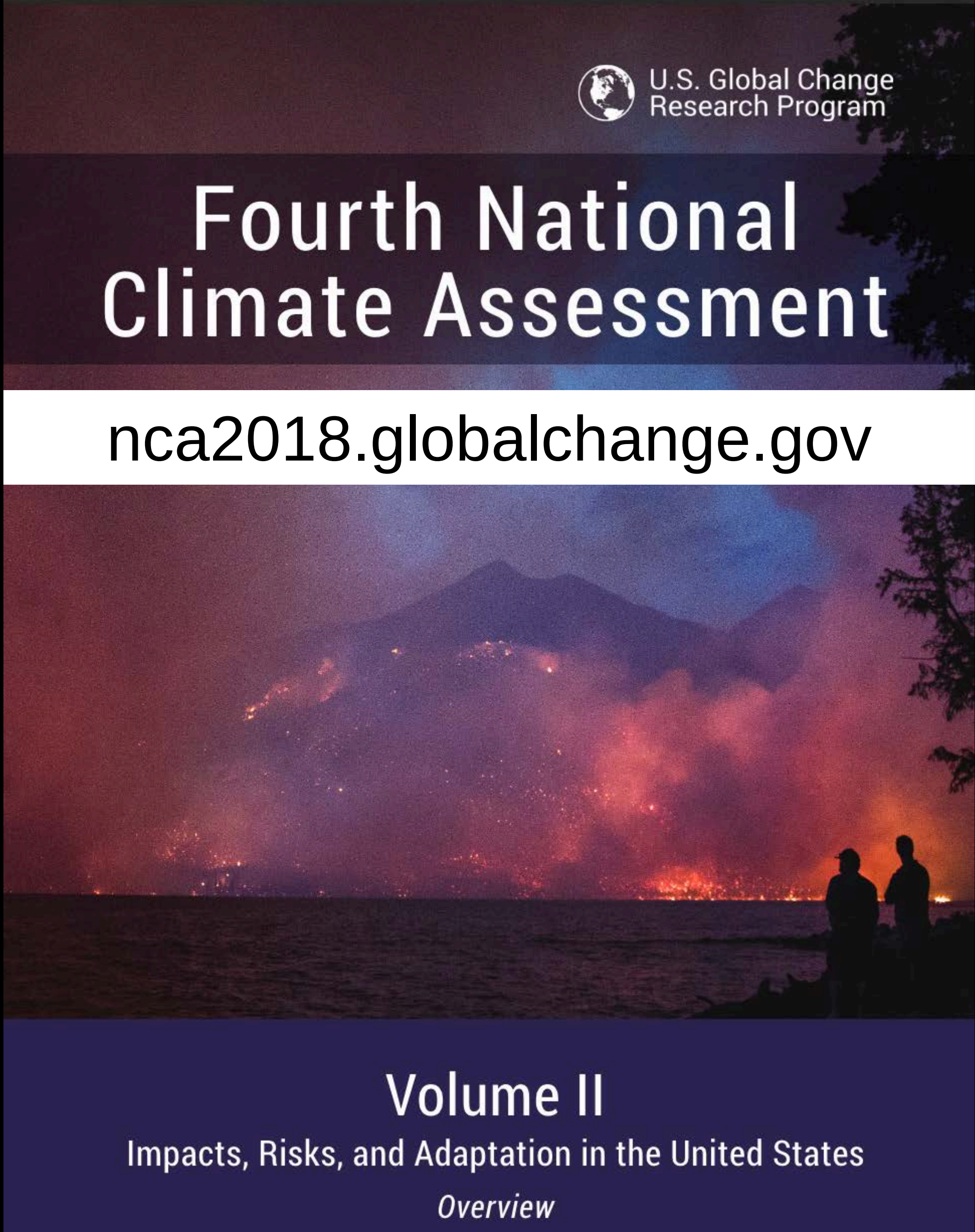


The Northeastern United States is Getting Warmer



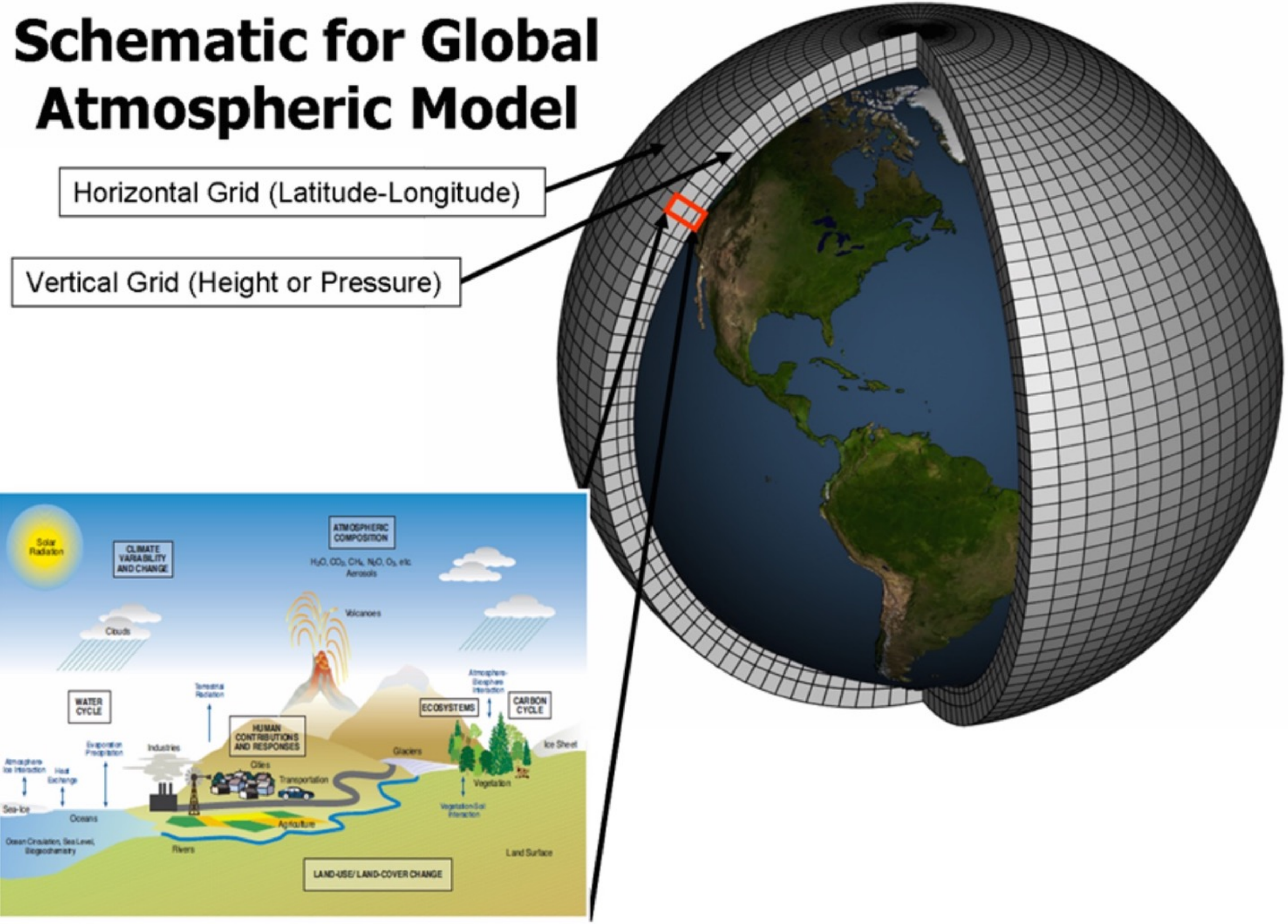
Volume II
Released
Nov. 2018

Impacts, risks, and adaptation



nca2018.globalchange.gov

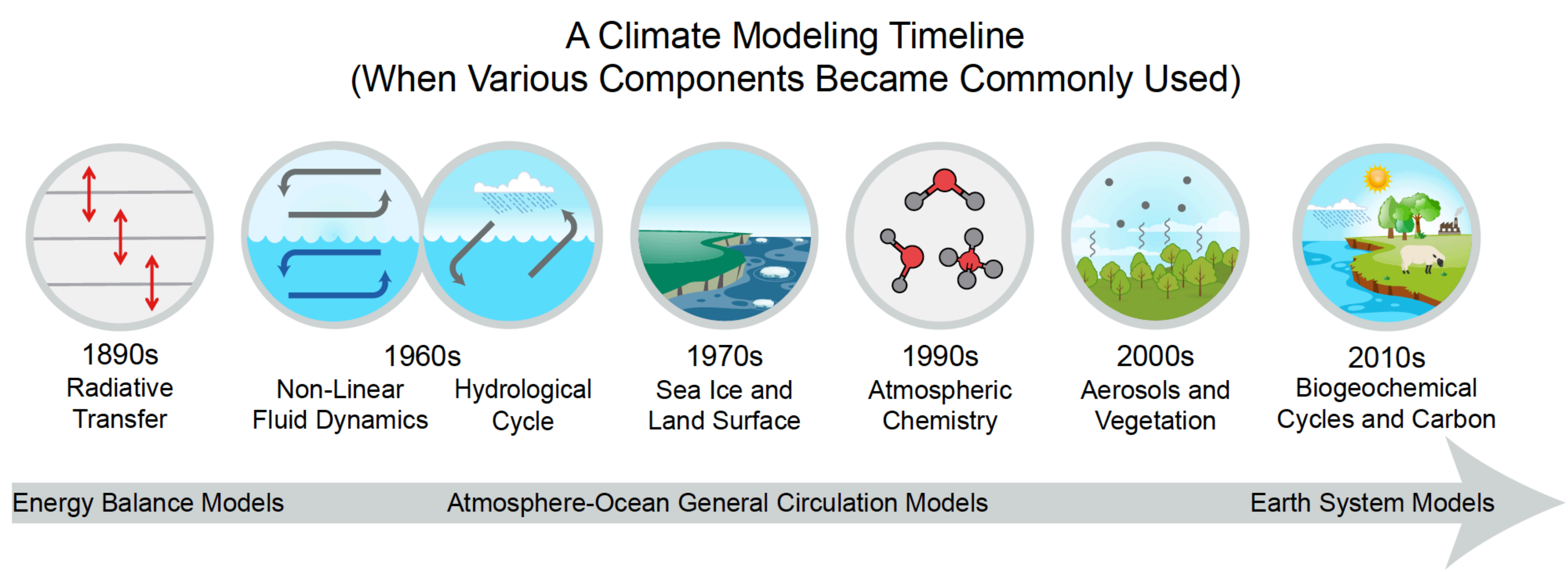
Schematic for Global Atmospheric Model



```fortran
    integer               :: varid                         ! netCDF id's
    integer               :: ier                           ! error status

    ! Open snow aging (effective radius evolution) file:
    allocate(snowage_tau(idx_rhos_max,idx_Tgrd_max,idx_T_max))
    allocate(snowage_kappa(idx_rhos_max,idx_Tgrd_max,idx_T_max))
    allocate(snowage_drdt0(idx_rhos_max,idx_Tgrd_max,idx_T_max))

    if(masterproc)  write(iulog,*) 'Attempting to read snow aging parameters .....'
    call getfil (fsnowaging, locfn, 0)
    call ncd_pio_openfile(ncid, locfn, 0)
    if(masterproc) write(iulog,*) subname,trim(fsnowaging)

     ! snow aging parameters

    call ncd_io('tau', snowage_tau,       'read', ncid, posNOTonfile=.true.)
    call ncd_io('kappa', snowage_kappa,   'read', ncid, posNOTonfile=.true.)
    call ncd_io('drdsdt0', snowage_drdt0, 'read', ncid, posNOTonfile=.true.)

    call ncd_pio_closefile(ncid)
    if (masterproc) then

       write(iulog,*) 'Successfully read snow aging properties'

       ! print some diagnostics:
       write (iulog,*) 'SNICAR: snowage tau for T=263K, dTdz = 100 K/m, rhos = 150 kg/m3: ', snowage_tau(3,11,9)
       write (iulog,*) 'SNICAR: snowage kappa for T=263K, dTdz = 100 K/m, rhos = 150 kg/m3: ', snowage_kappa(3,11,9)
       write (iulog,*) 'SNICAR: snowage dr/dt_0 for T=263K, dTdz = 100 K/m, rhos = 150 kg/m3: ', snowage_drdt0(3,11,9)
    endif

  end subroutine SnowAge_init


end module SNICARMod
                                                                                    1433,1        Bot
```

```
if ((albedo < 0._r8).and.(trip==0)) then
   trip = 1
endif

! Set conditions for redoing RT calculation
if ((trip == 1).and.(flg_dover == 1)) then
   flg_dover = 2
elseif ((trip == 1).and.(flg_dover == 2)) then
   flg_dover = 3
elseif ((trip == 1).and.(flg_dover == 3)) then
   flg_dover = 4
elseif((trip == 1).and.(flg_dover == 4).and.(err_idx < 20)) then
   flg_dover = 3
   err_idx = err_idx + 1
elseif((trip == 1).and.(flg_dover == 4).and.(err_idx >= 20)) then
   flg_dover = 0
   write(iulog,*) "SNICAR ERROR: FOUND A WORMHOLE. STUCK IN INFINITE LOOP! Called from: ", flg_snw_ice
   write(iulog,*) "SNICAR STATS: snw_rds(0)= ", snw_rds(c_idx,0)
   write(iulog,*) "SNICAR STATS: L_snw(0)= ", L_snw(0)
   write(iulog,*) "SNICAR STATS: h2osno= ", h2osno_lcl, " snl= ", snl_lcl
   write(iulog,*) "SNICAR STATS: soot1(0)= ", mss_cnc_aer_lcl(0,1)
   write(iulog,*) "SNICAR STATS: soot2(0)= ", mss_cnc_aer_lcl(0,2)
   write(iulog,*) "SNICAR STATS: dust1(0)= ", mss_cnc_aer_lcl(0,3)
   write(iulog,*) "SNICAR STATS: dust2(0)= ", mss_cnc_aer_lcl(0,4)
   write(iulog,*) "SNICAR STATS: dust3(0)= ", mss_cnc_aer_lcl(0,5)
   write(iulog,*) "SNICAR STATS: dust4(0)= ", mss_cnc_aer_lcl(0,6)
   l_idx     = col%landunit(c_idx)
   write(iulog,*) "column index: ", c_idx
   write(iulog,*) "landunit type", lun%itype(l_idx)
   write(iulog,*) "frac_sno: ", frac_sno(c_idx)
   call endrun(decomp_index=c_idx, clmlevel=namec, msg=errmsg(__FILE__, __LINE__))
else
   flg_dover = 0
endif
-- INSERT --                                                          898,33        63%
```

So what is a climate model?

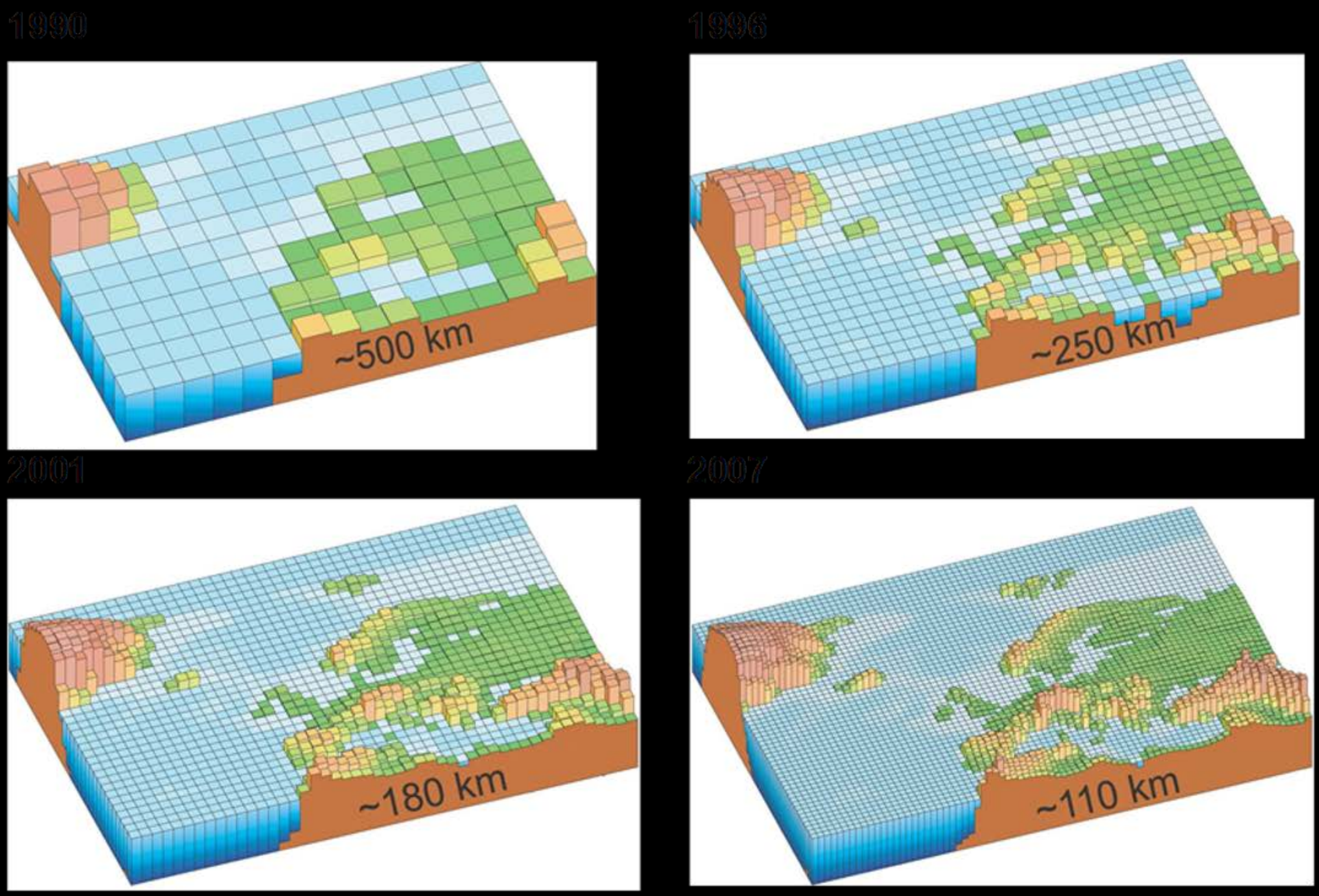


"Simple"

Complex

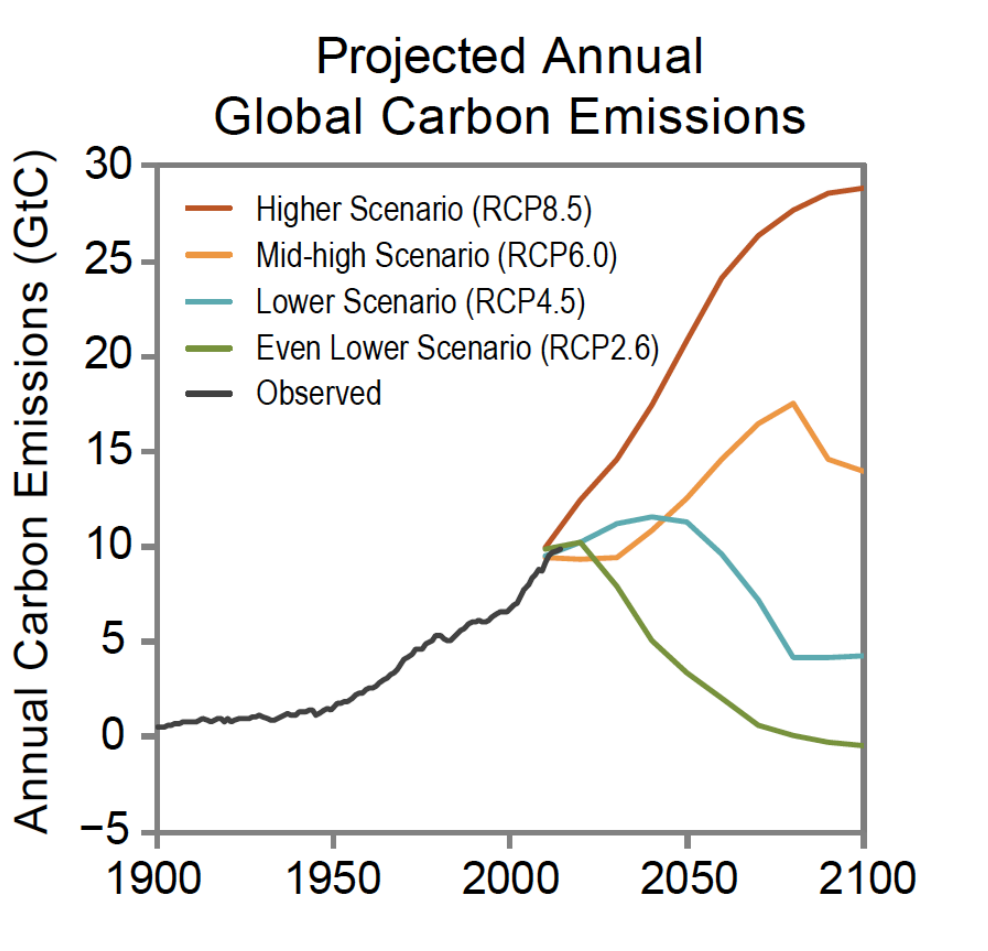
Chapter 4, Figure 4.3; NCA4/CSSR.

Resolution – grid spacing – has gotten finer



Chapter 4, Figure 4.3; NCA4/CSSR.

Climate Scenarios: Greater greenhouse gas emissions lead to significantly more warming



RCP:

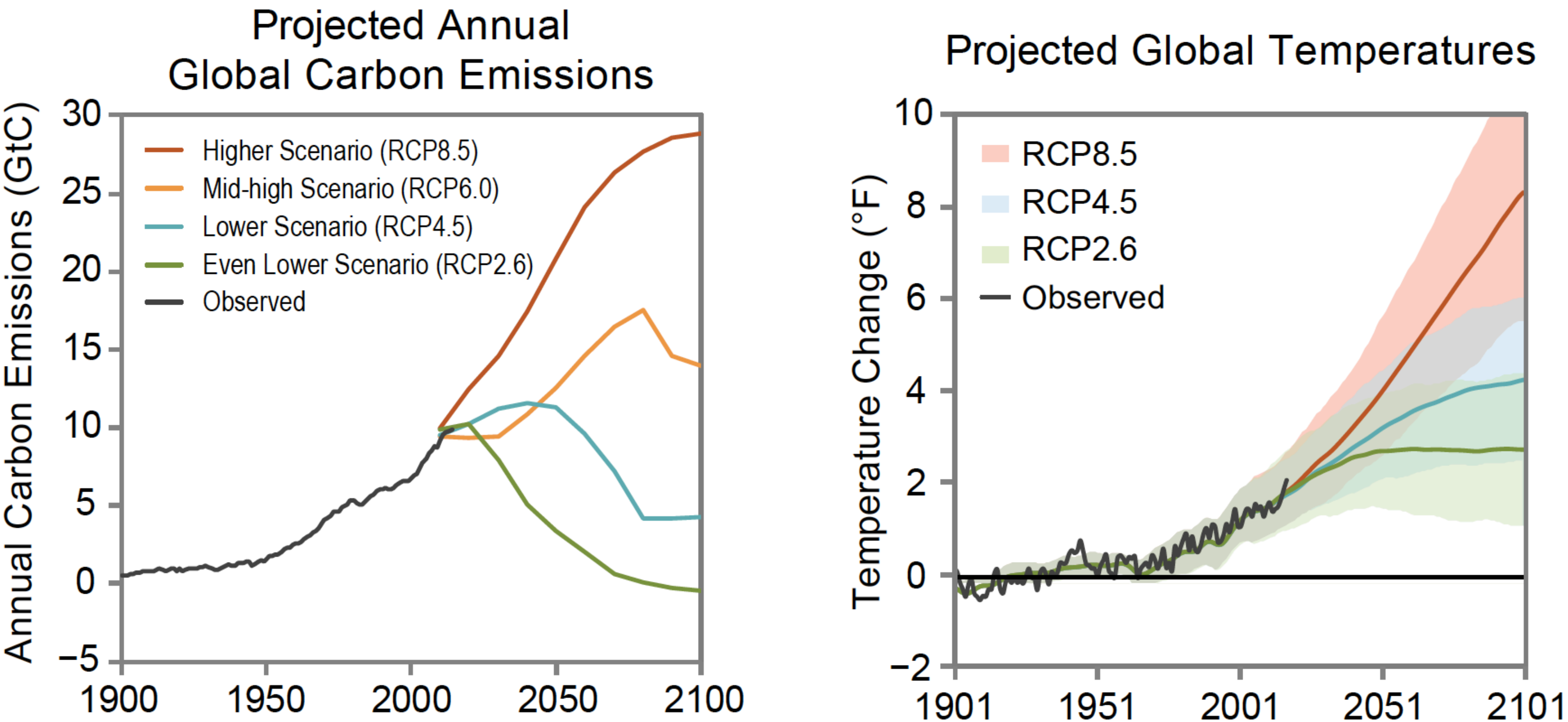
Representative

Concentration

Pathway

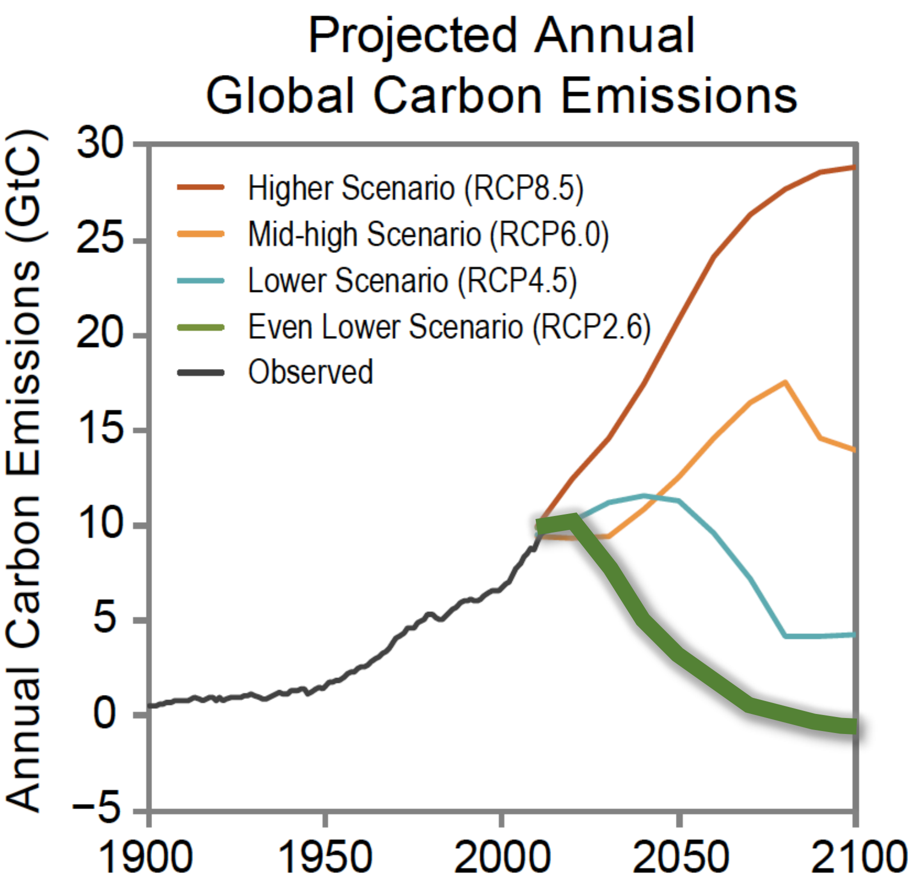
RCP8.5 = 8.5 W/m^2

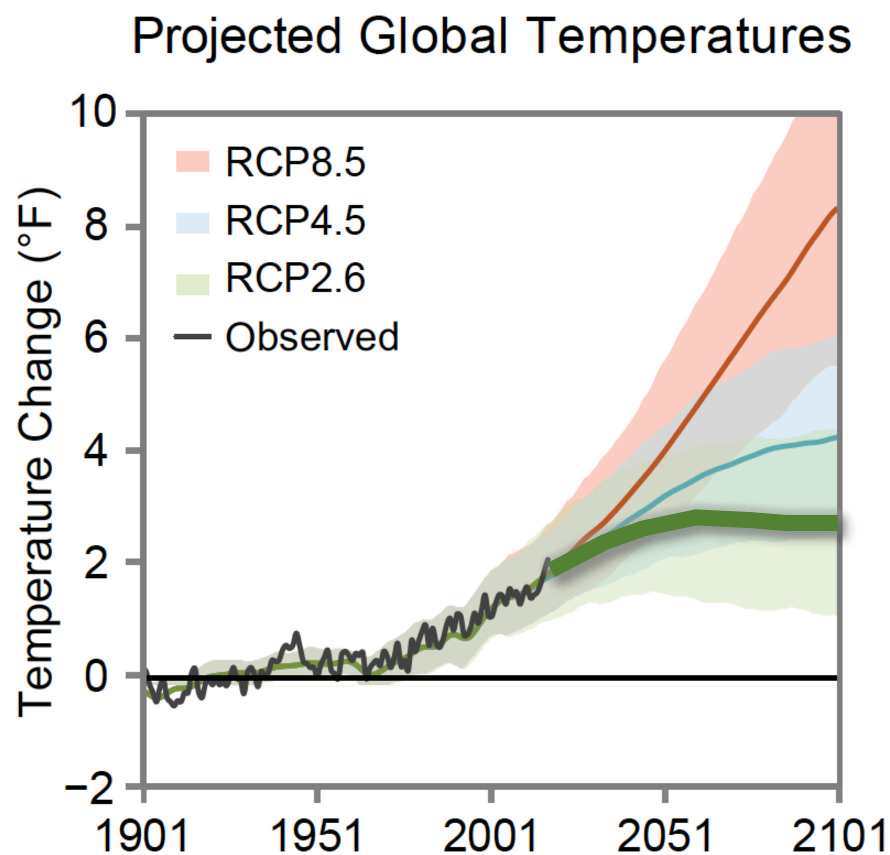
Climate Scenarios:
Lowest scenario ~ “Paris Agreement”



"Paris Agreement"

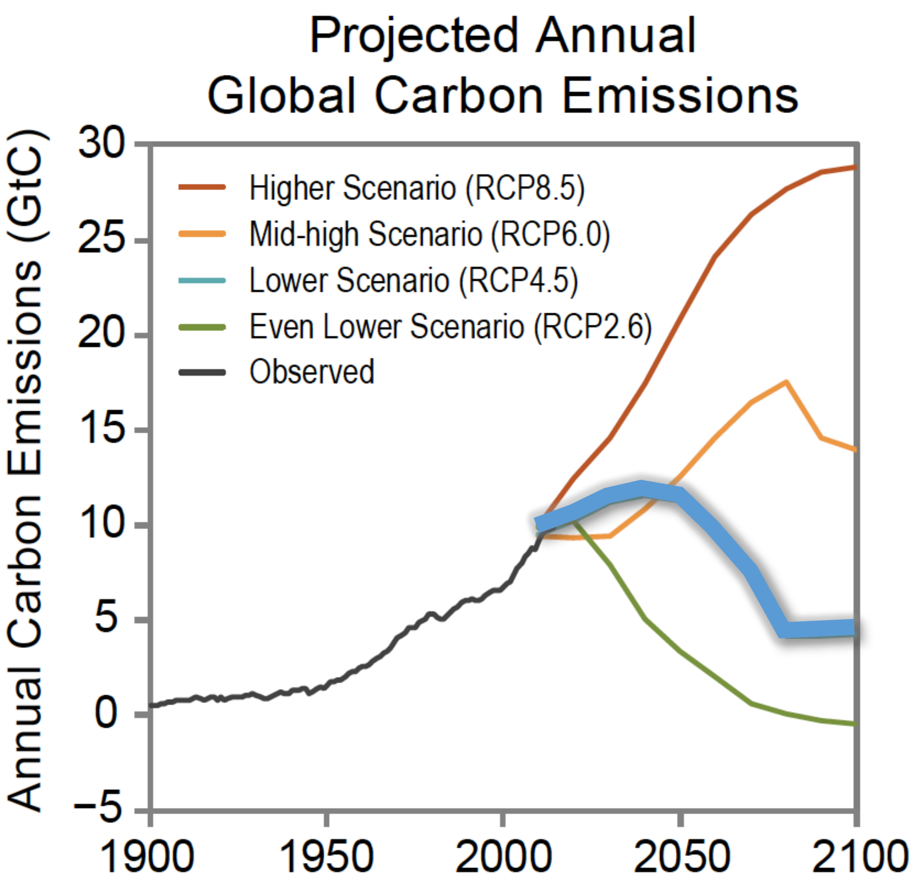
limit warming to 2.8ºF

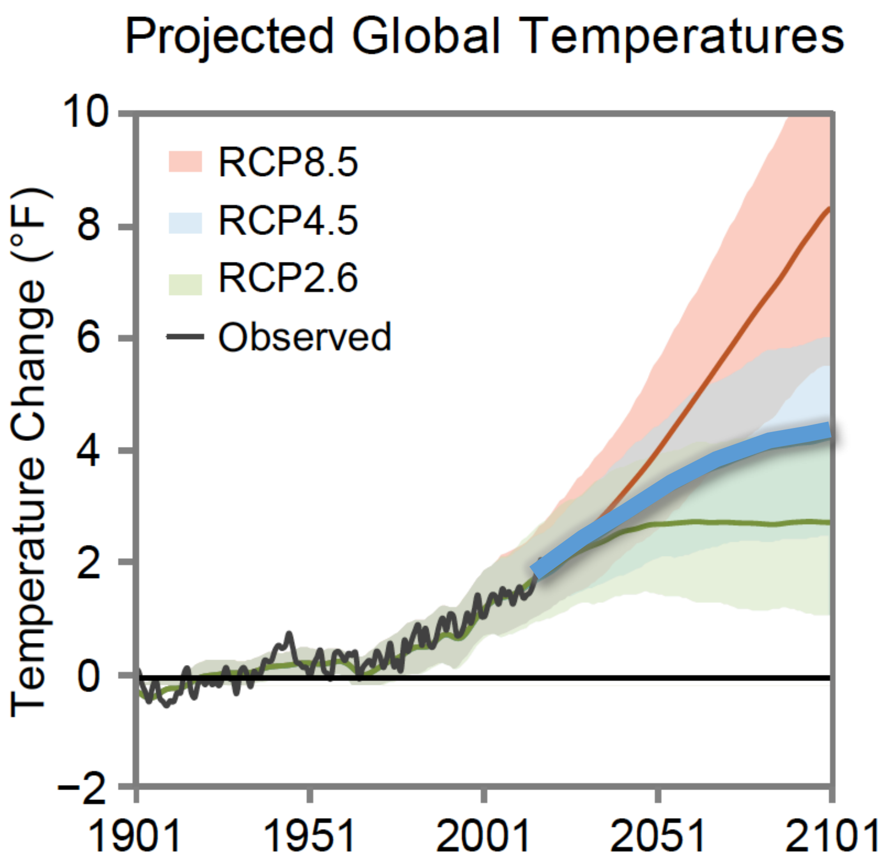




Lower Scenario

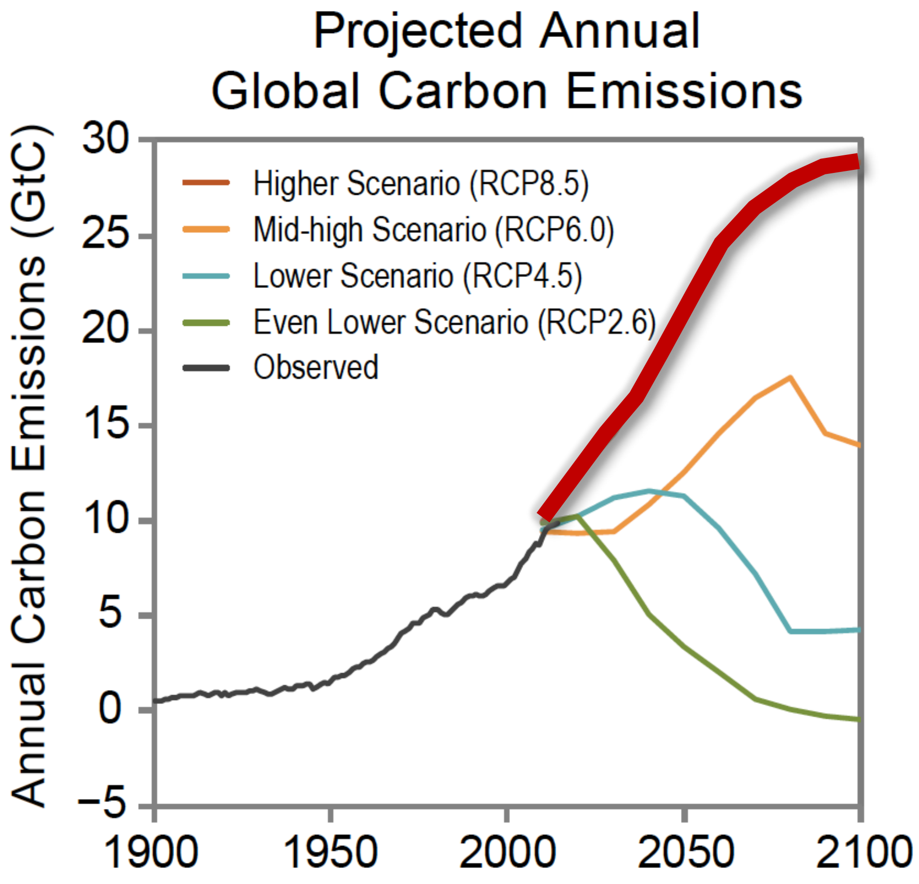
limit warming to 4.3ºF

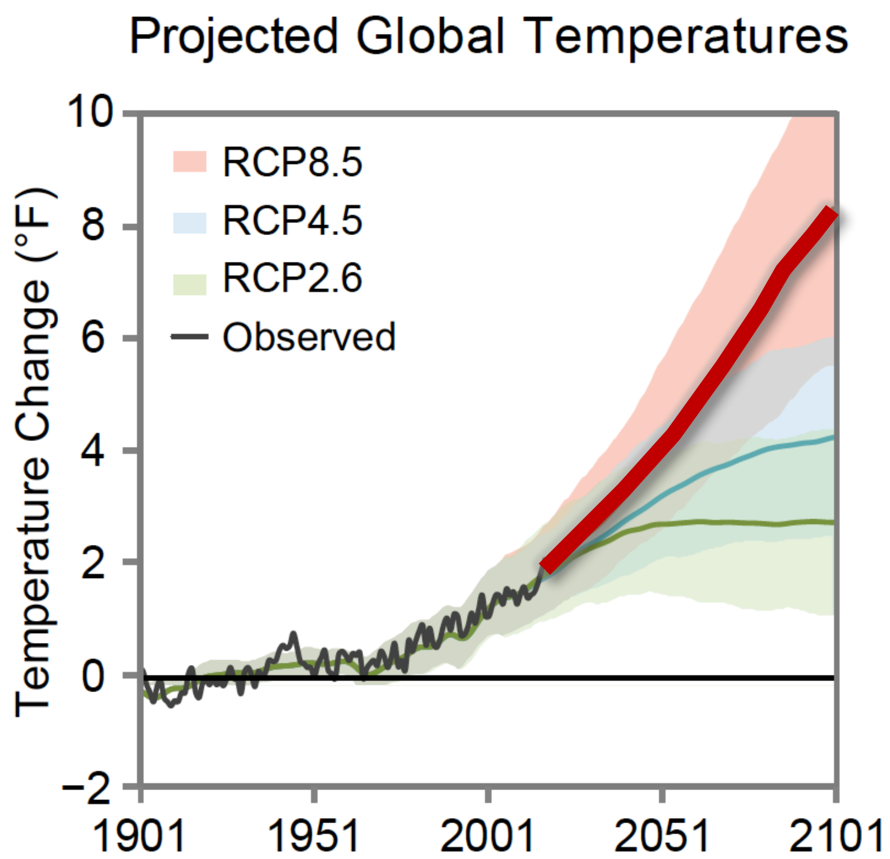




Highest Scenario

unmitigated warming +7.7ºF

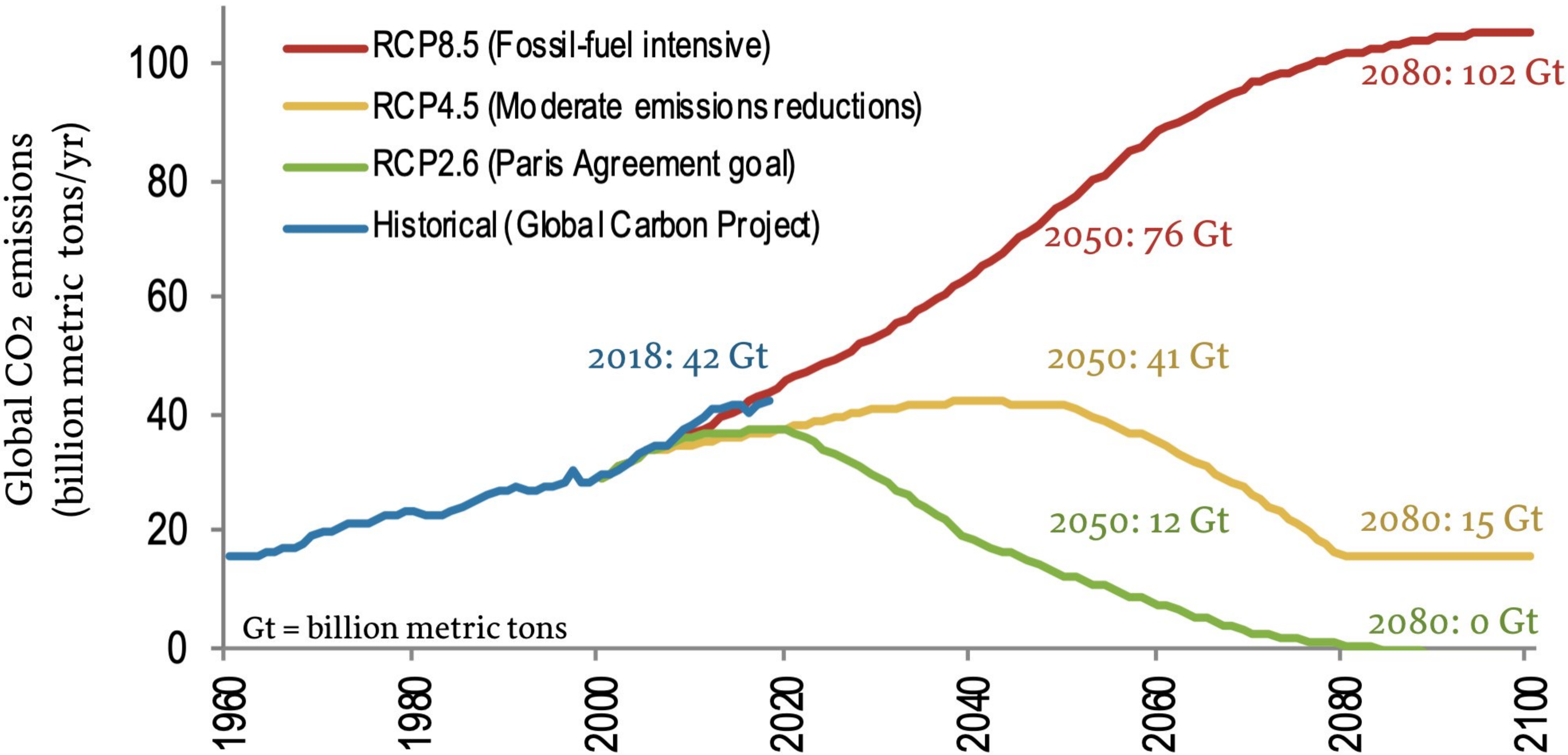




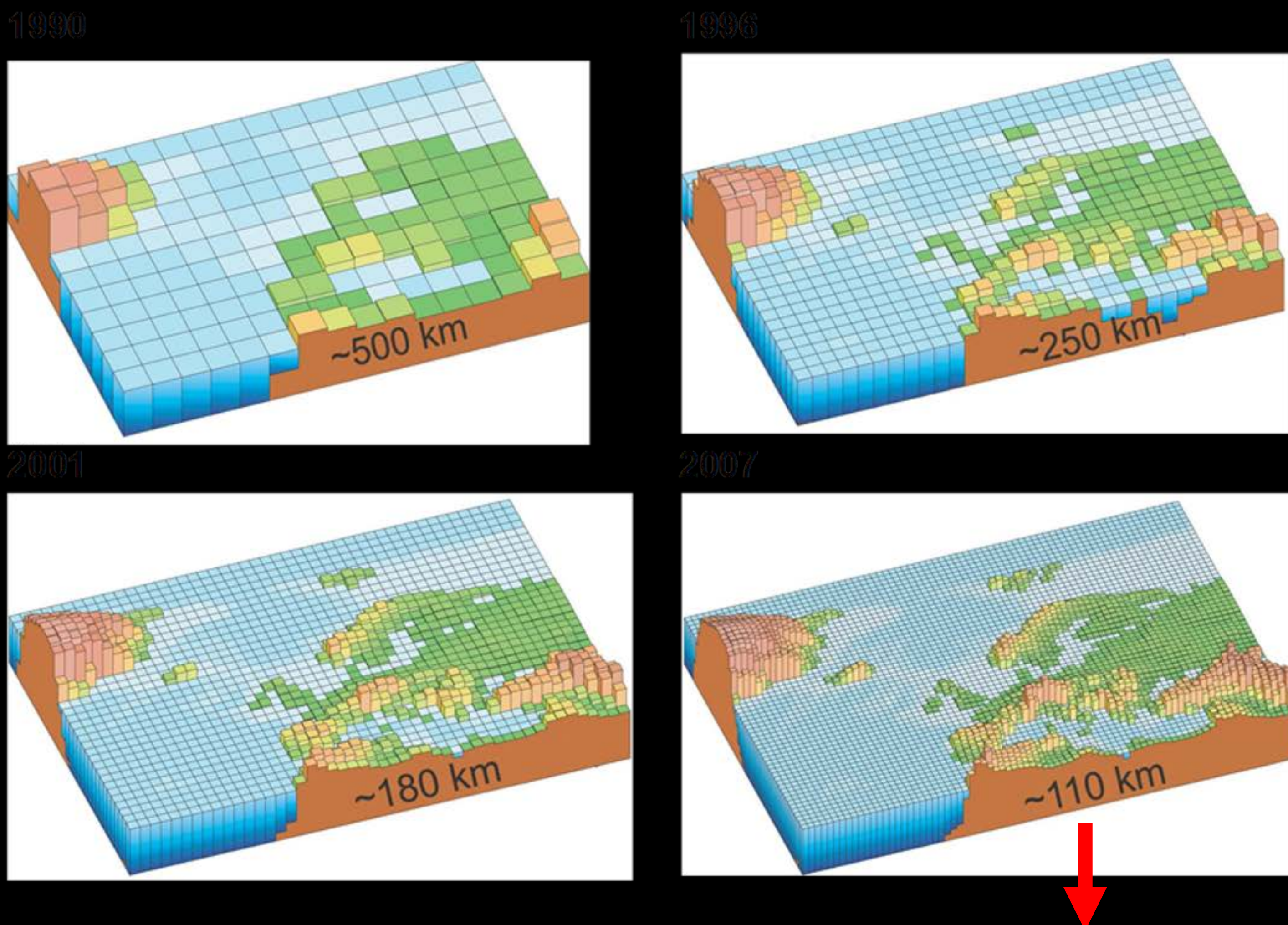
Which scenario are we currently following?

A. "Paris Agreement"
B. Lower scenario
C. Highest scenario

We are currently tracking the higher scenario

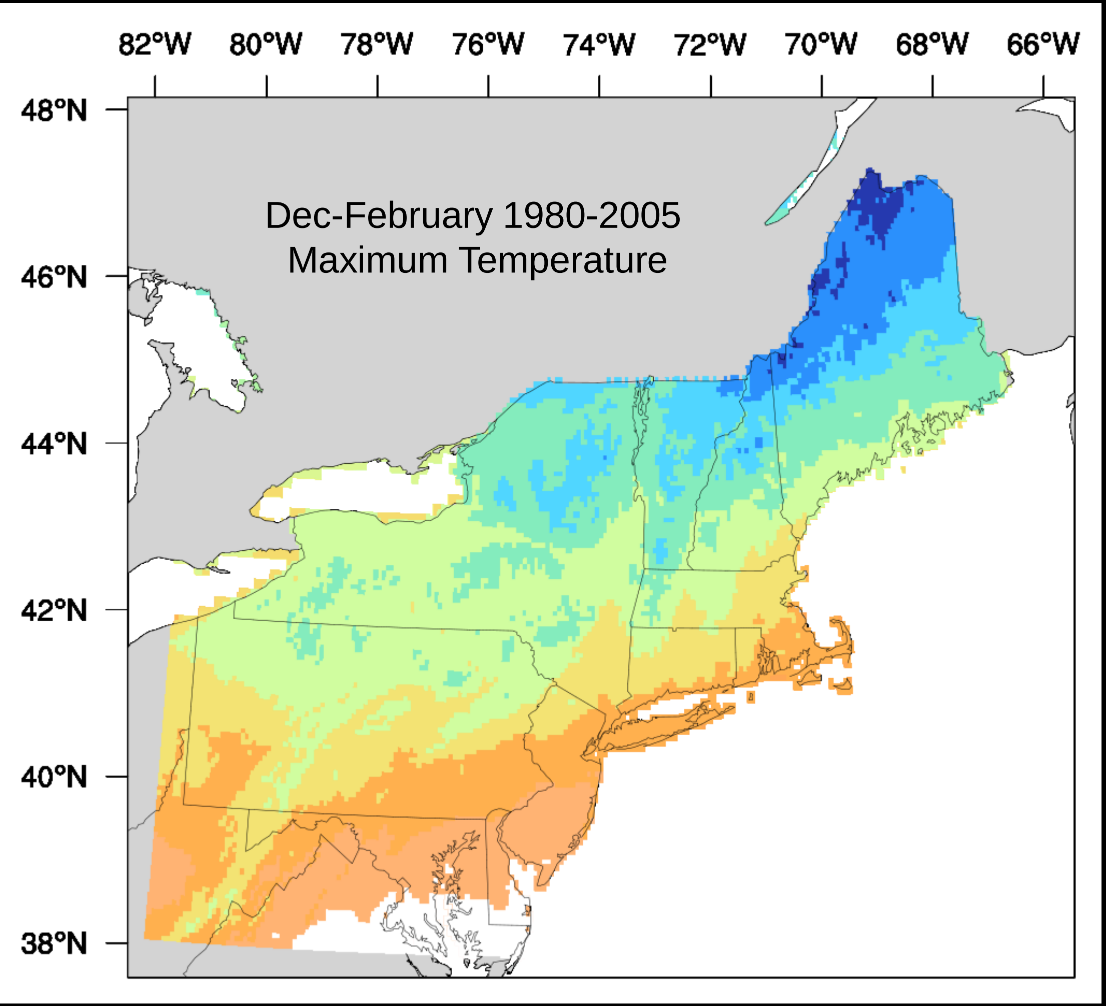


Resolution – grid spacing – has gotten finer



Statistical downscaling 7 km

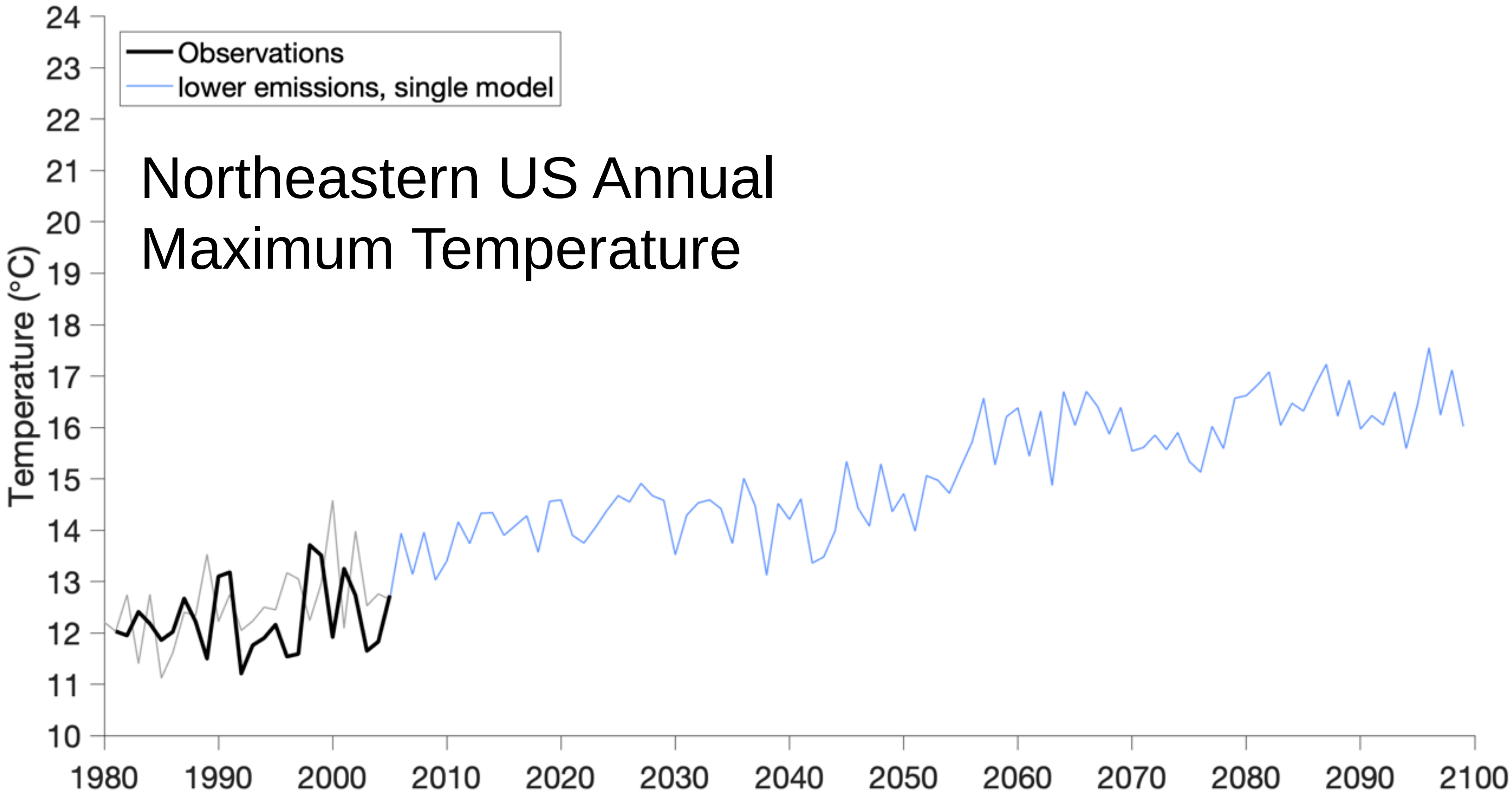
Northeastern US Climate Projections



- 7 km grid cells
- 1980-2099
- 29 different climate models
- Highest climate scenario & lower climate scenario

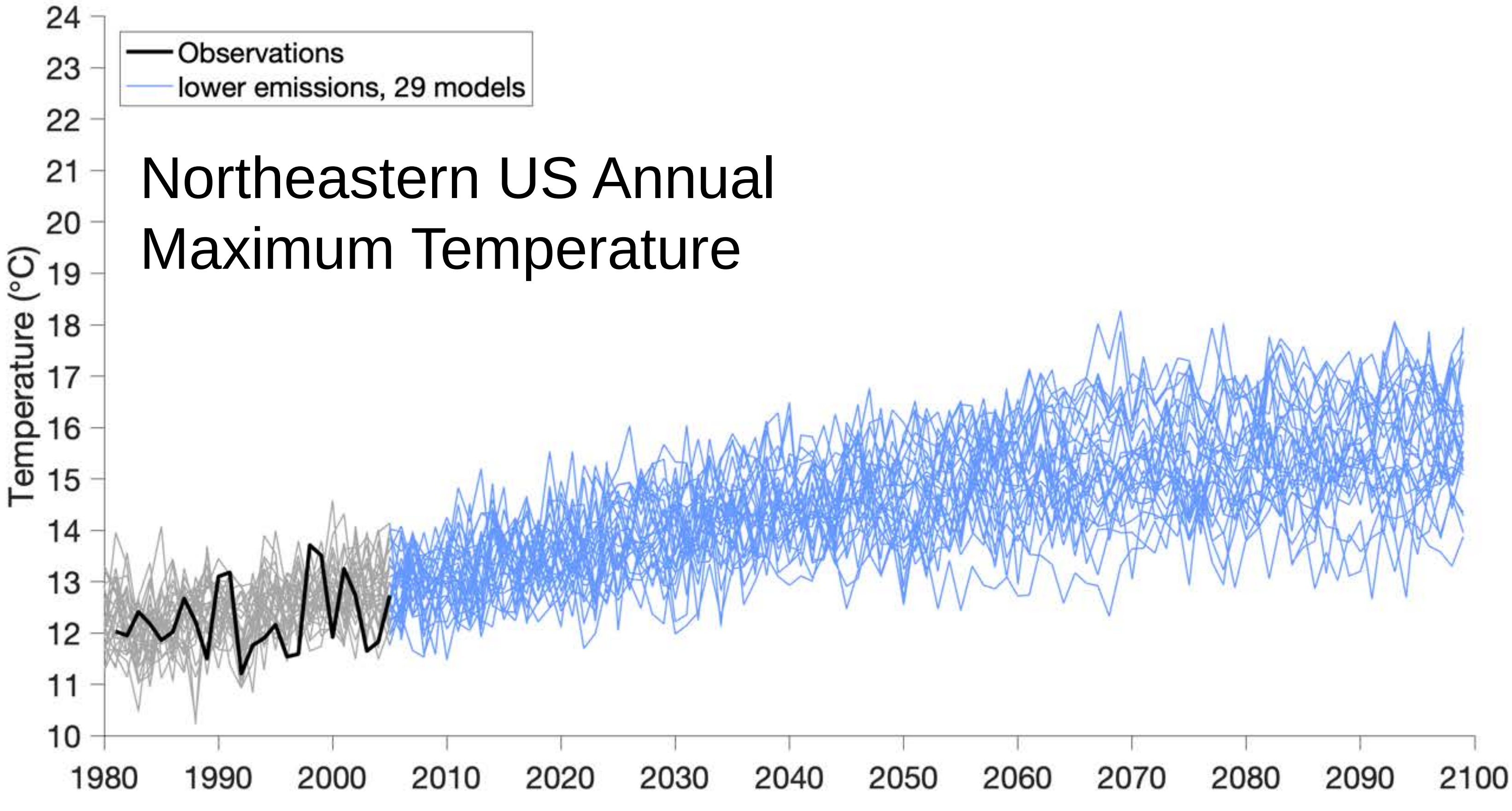
Pierce et al. 2014, *J. Hydromet*

Each thin line is a single climate model run. Black line is observed.



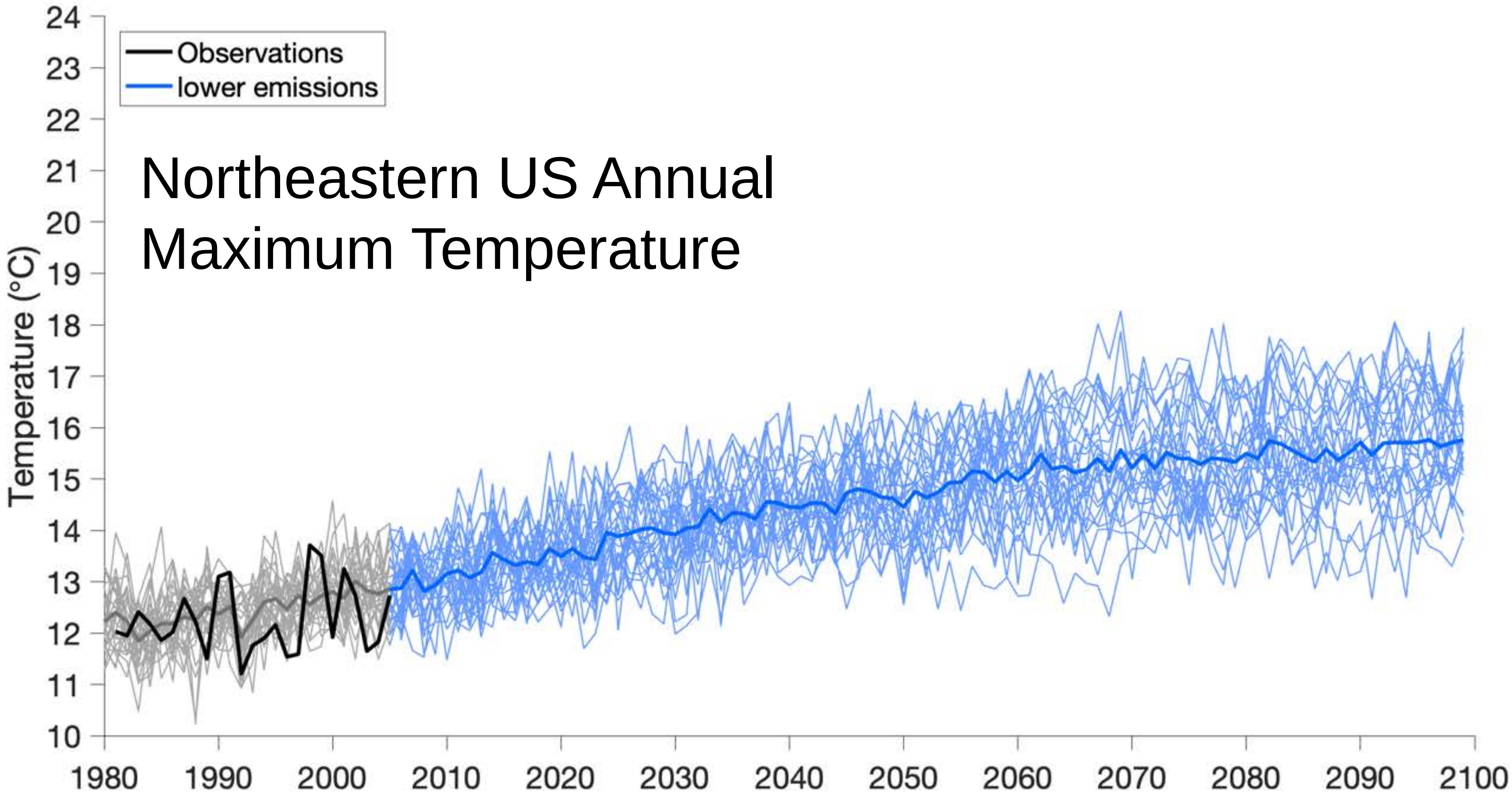
Burakowski et al. *in prep*

Run 29 different models using the lower emissions scenario (RCP4.5).



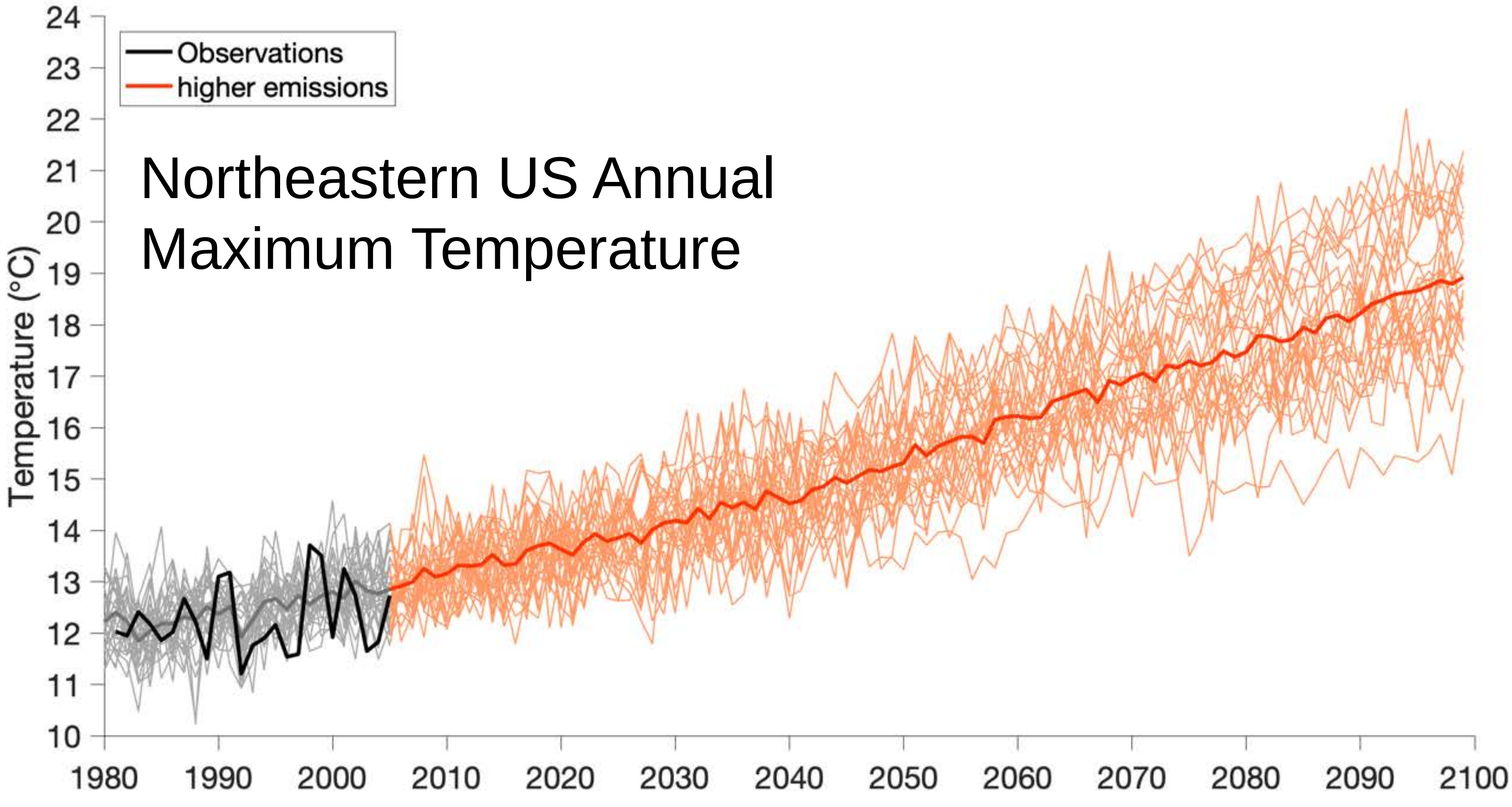
Burakowski et al. *in prep*

Calculate the average of the 29 different models (thick blue line).



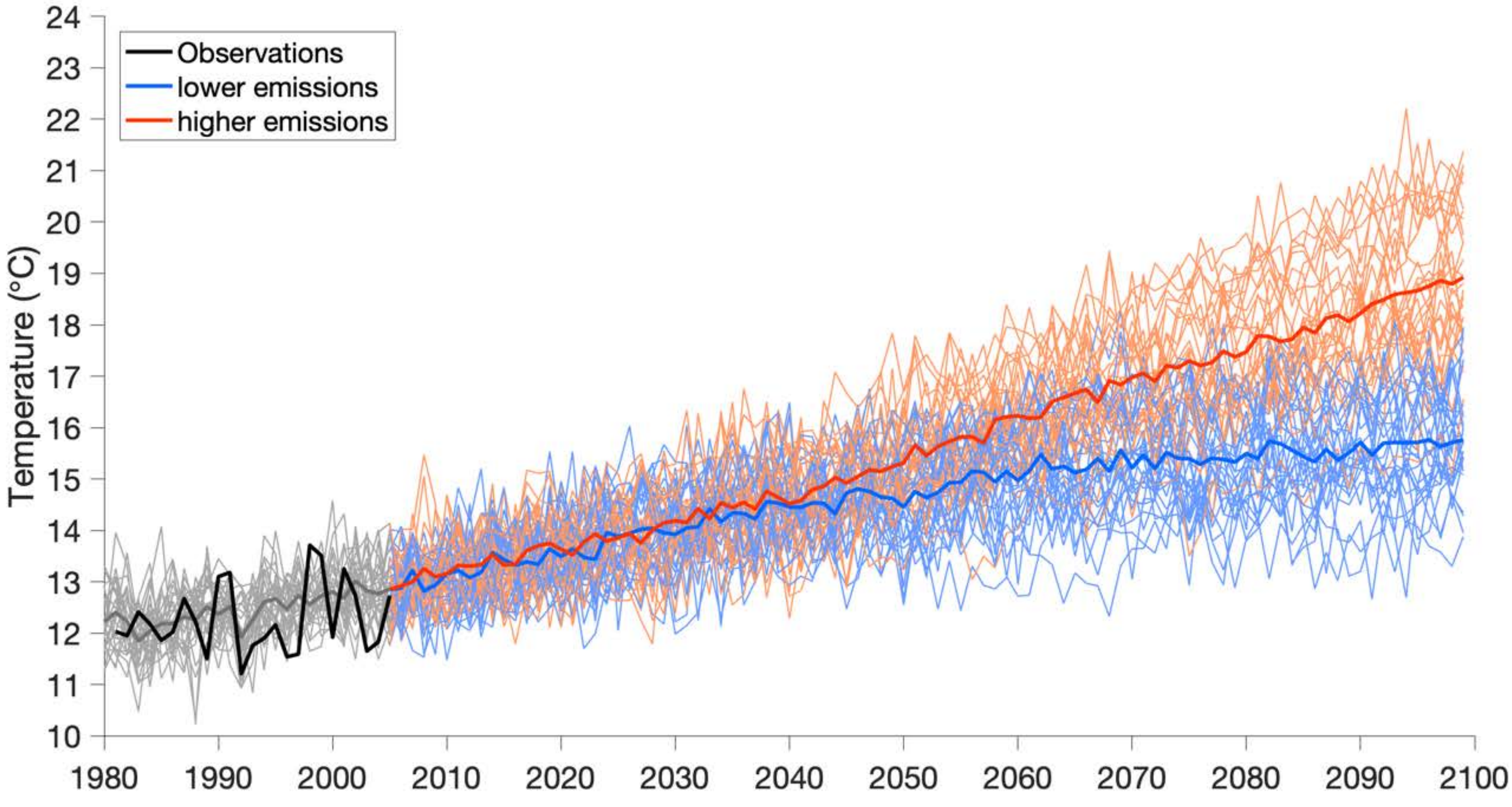
Burakowski et al. *in prep*

Repeat the 29 model runs using the higher emissions scenario.



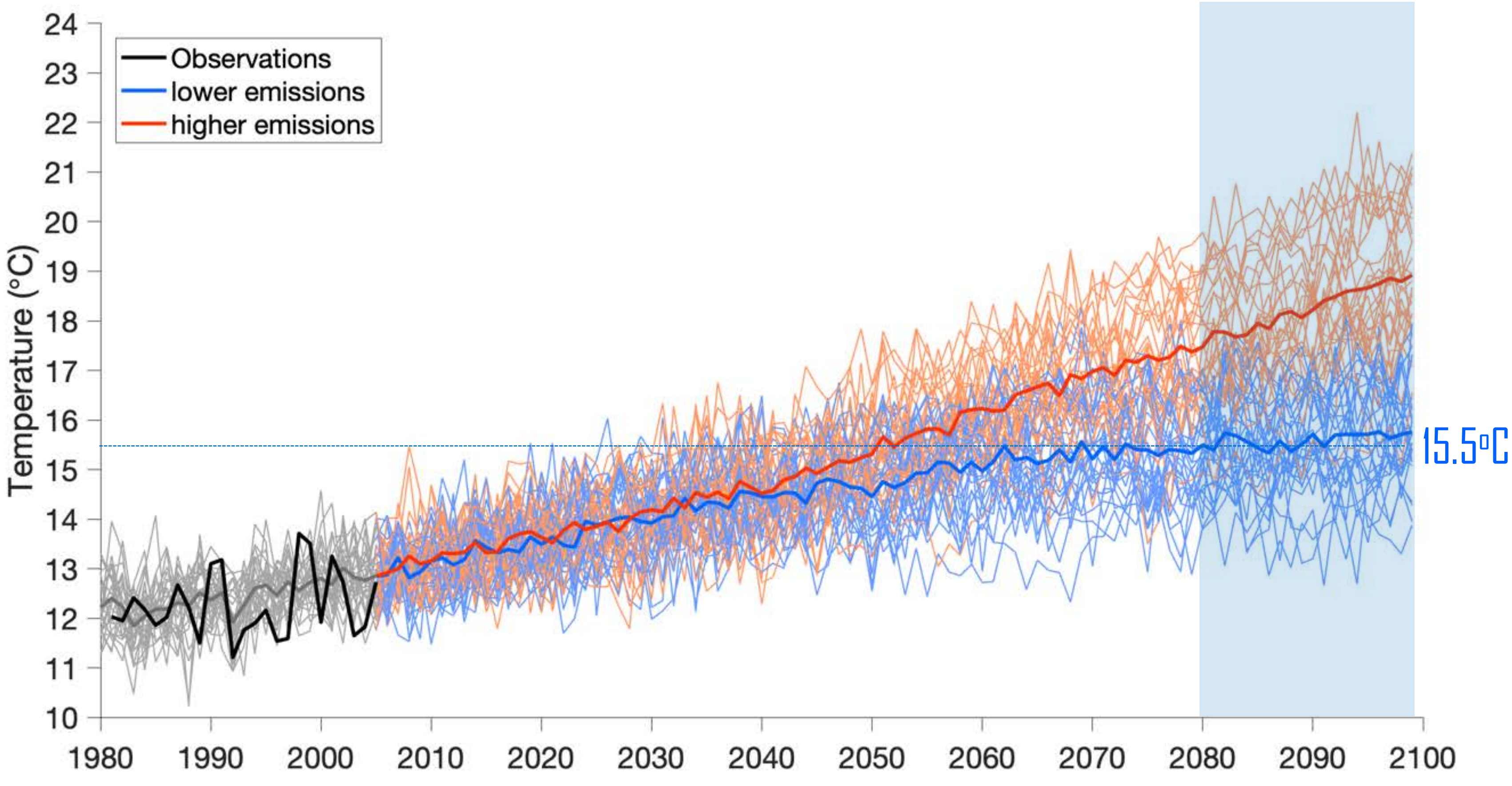
Burakowski et al. *in prep*

Compare the lower emissions scenario to the higher emissions scenario.



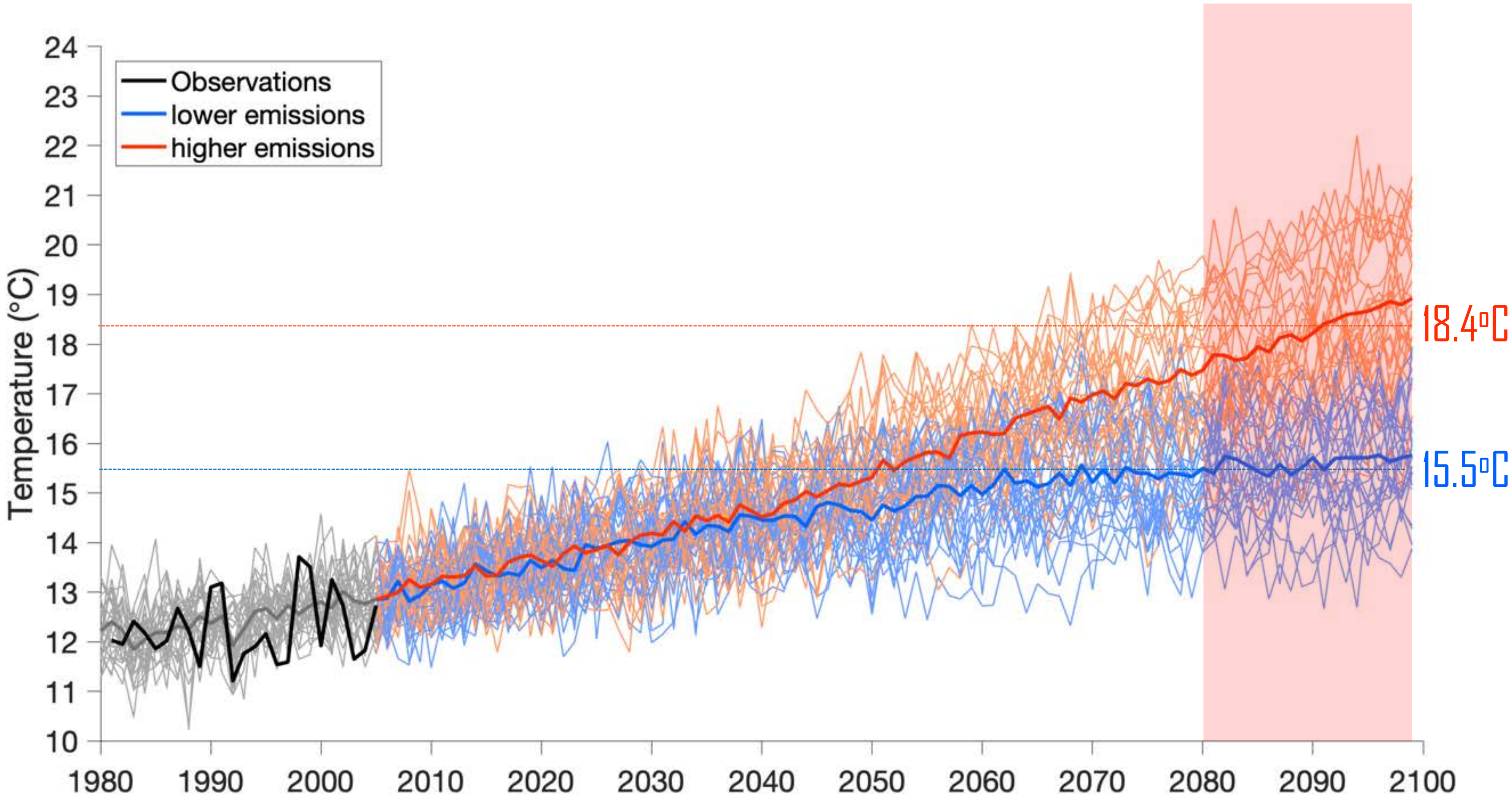
Burakowski et al. *in prep*

Compare the lower emissions scenario to the higher emissions scenario.



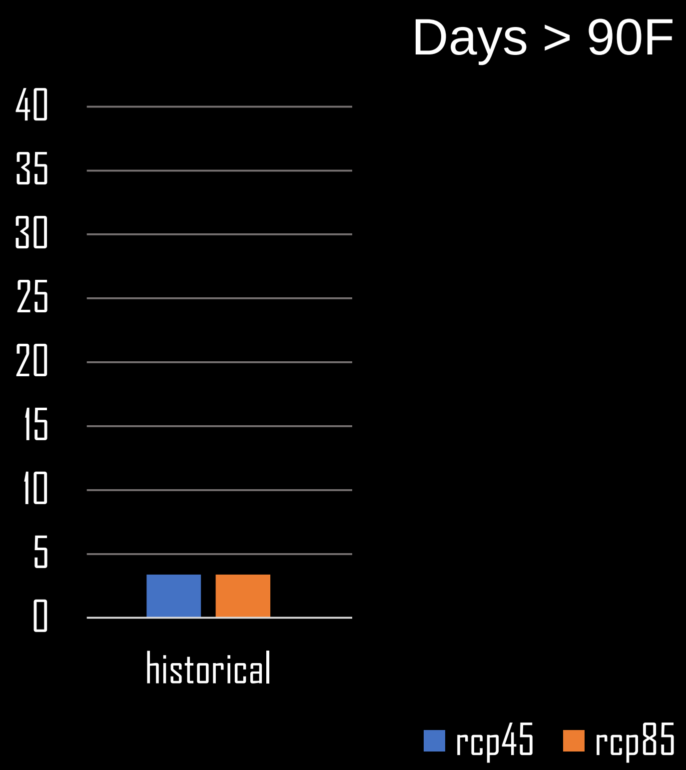
Burakowski et al. *in prep*

Compare the lower emissions scenario to the higher emissions scenario.

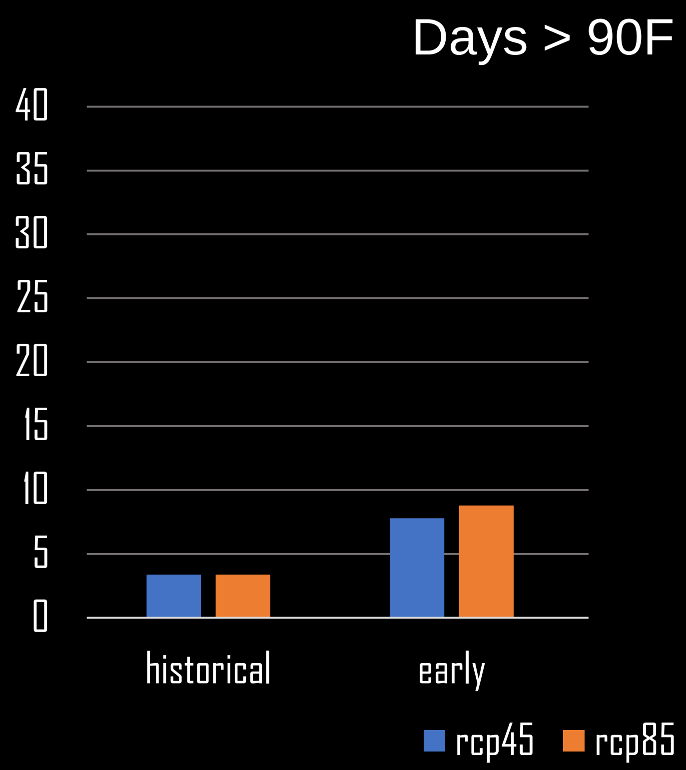


Burakowski et al. *in prep*

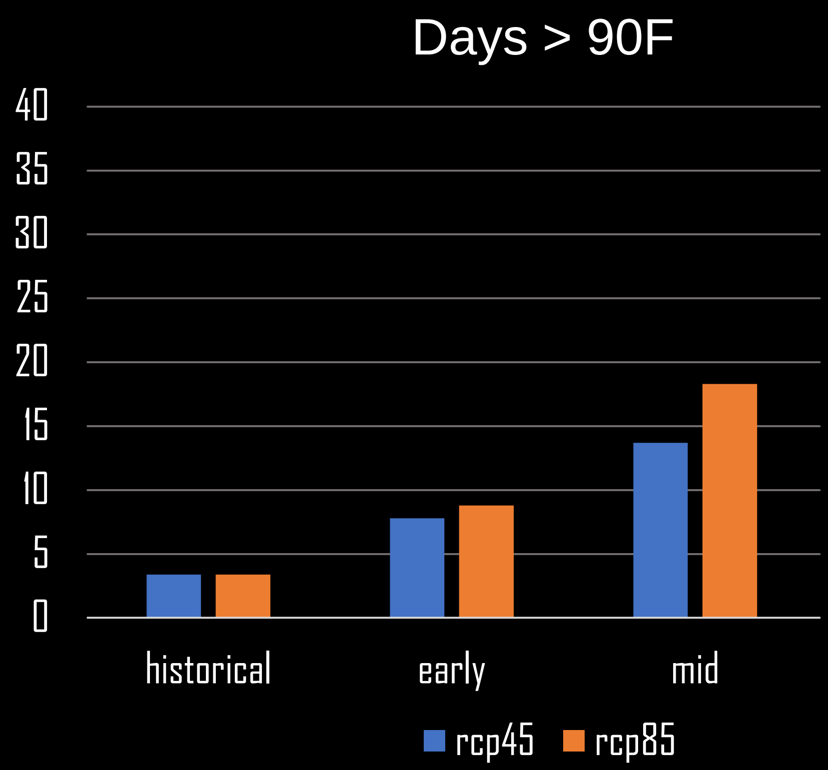
Future Projections: Extreme Temperature



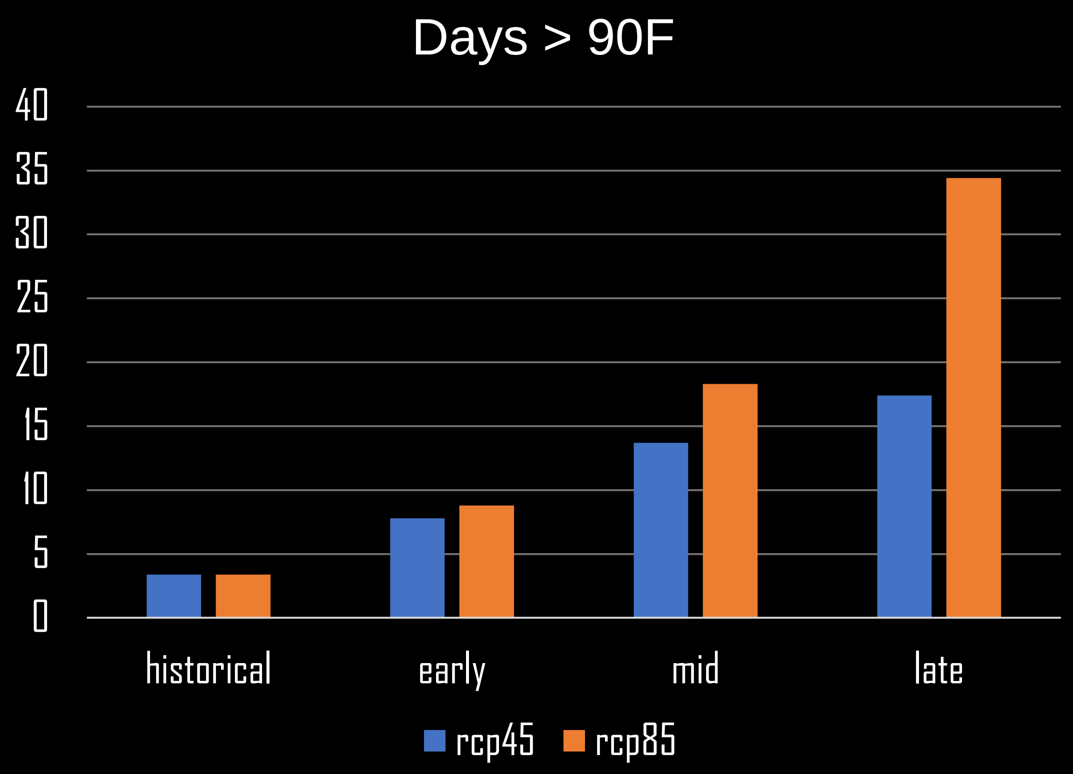
Future Projections: Extreme Temperature



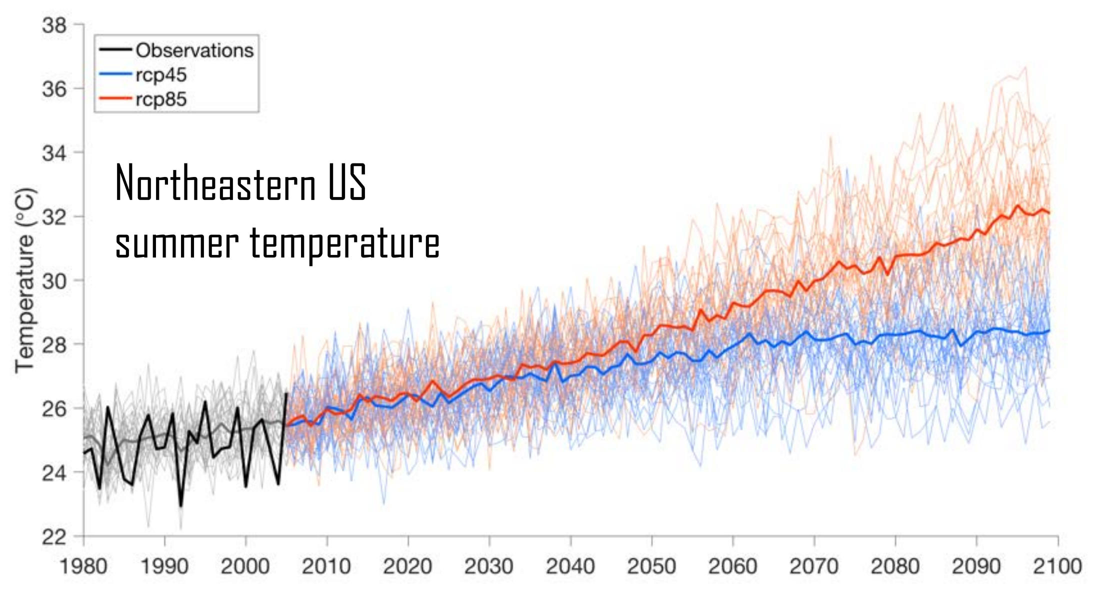
Future Projections: Extreme Temperature



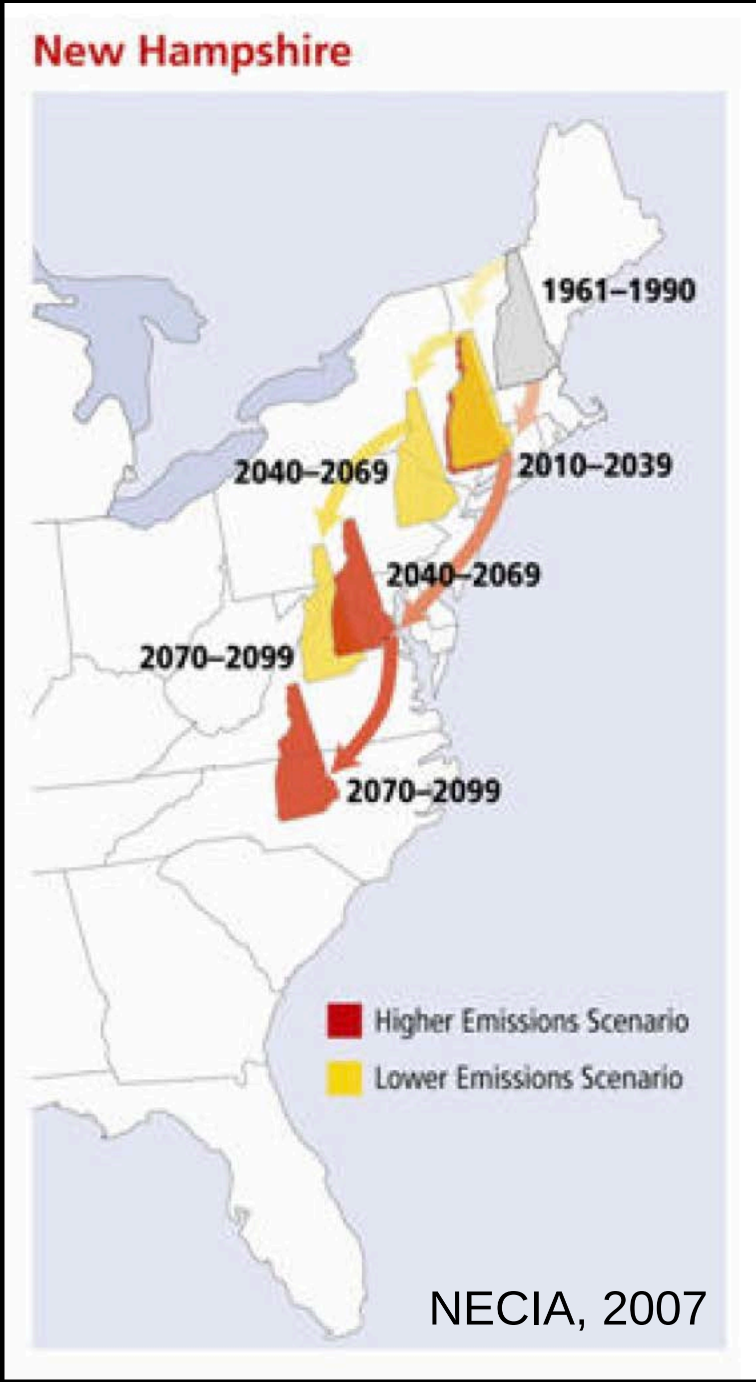
Future Projections: Extreme Temperature



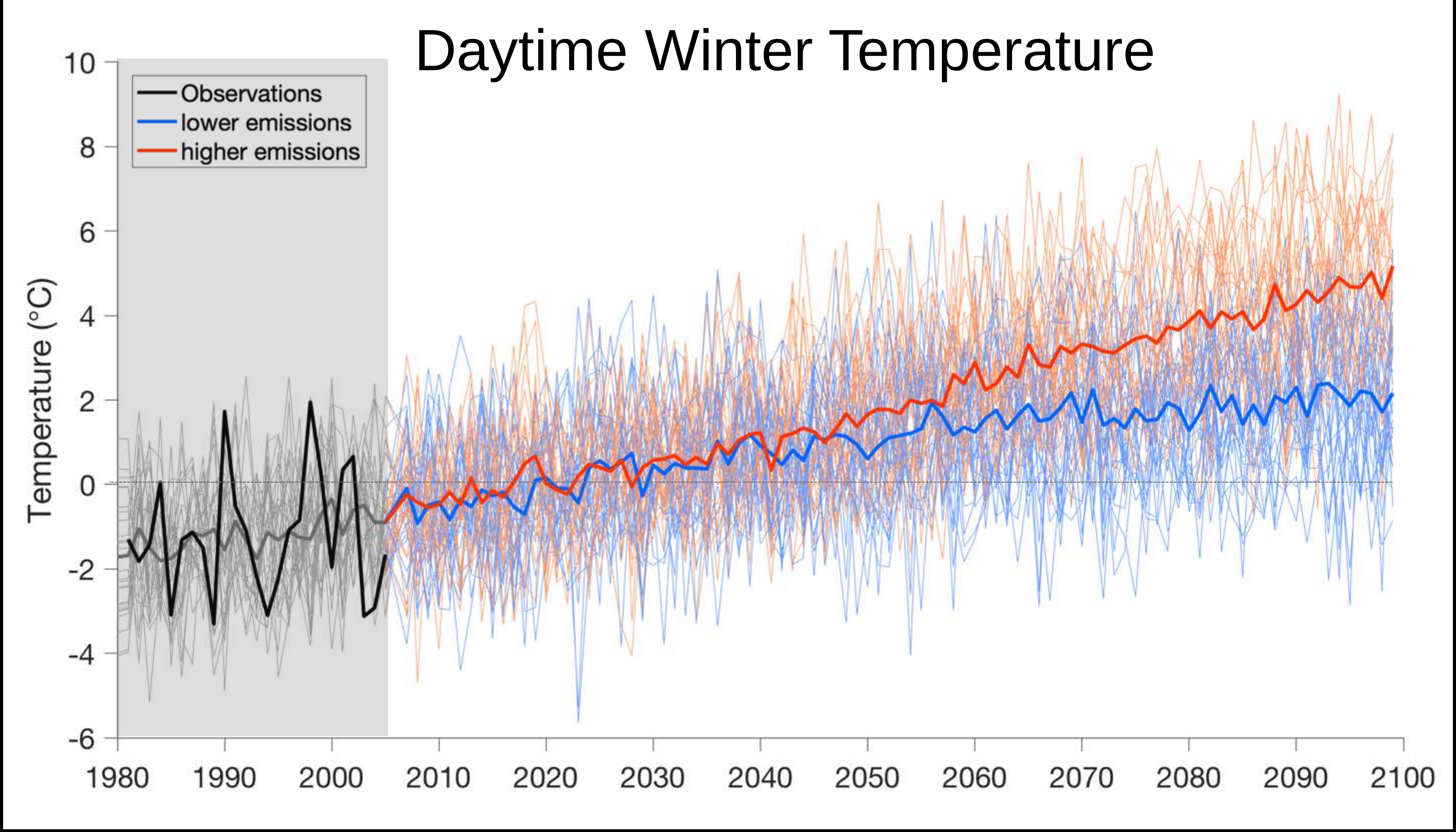
NH's warming summers



- Under lower emissions, like moving NH summer climate to Virginia.
- Under higher emissions, closer to North Carolina.

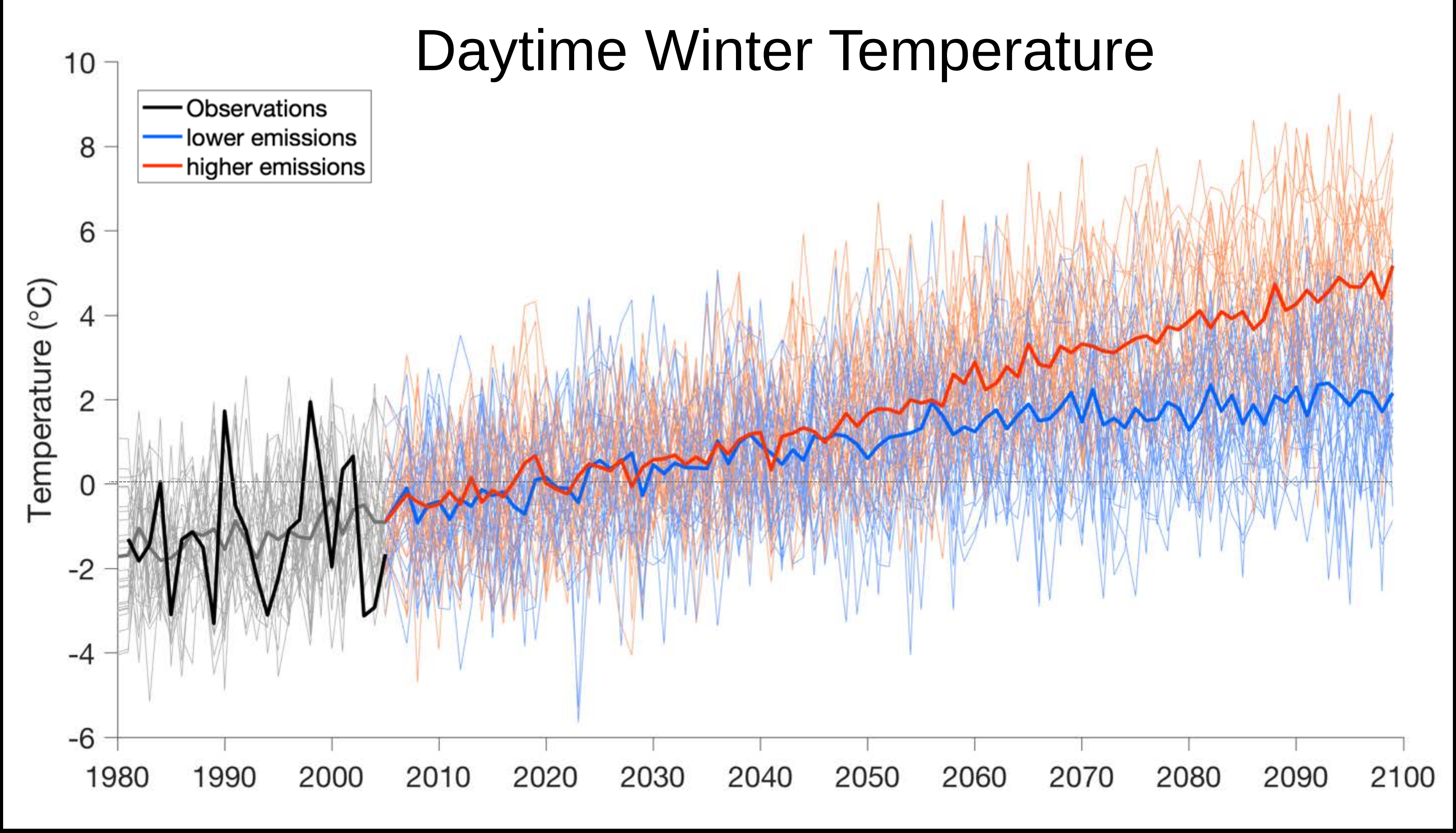


Historically, most Northeastern US winters have below-freezing average daytime temperatures.



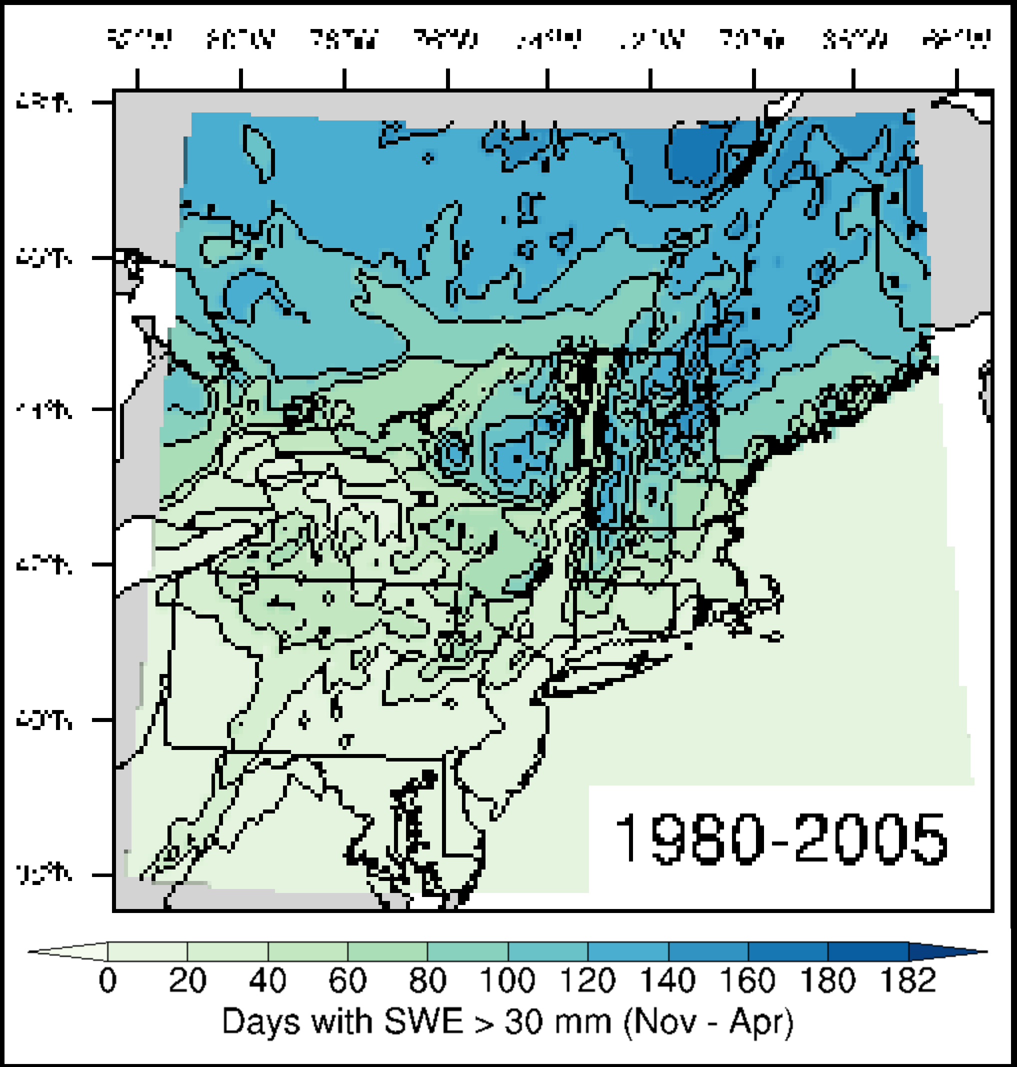
Burakowski et al. *in prep*

Under lower emissions, it is much less likely to see below freezing daytime high temperatures.



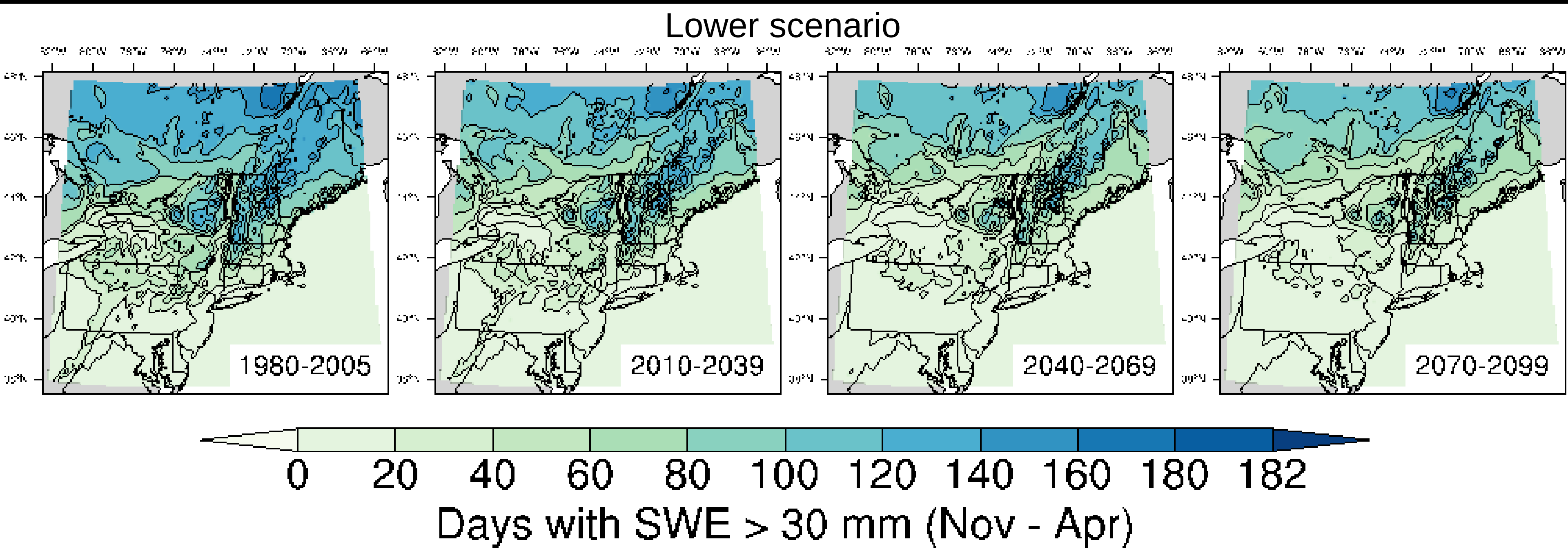
Burakowski et al. *in prep*

Historical number of days with snow depth greater than ~ 6 inches



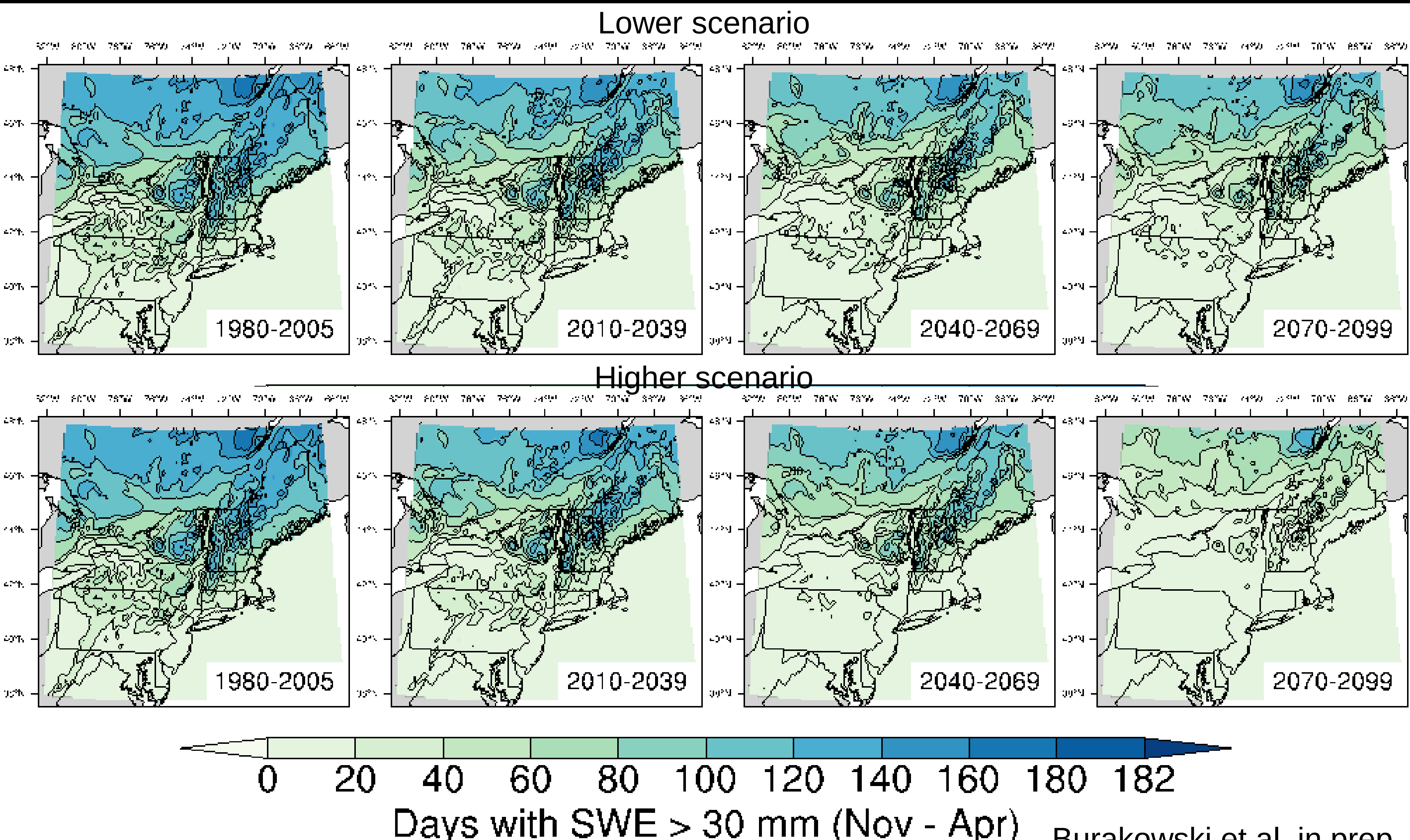
Burakowski et al. in prep

Under the lower scenario, headwaters still have about 100 days of snow cover.



Burakowski et al. in prep

Under higher scenario, only ~60 days with snow cover > 6” at the highest elevations.

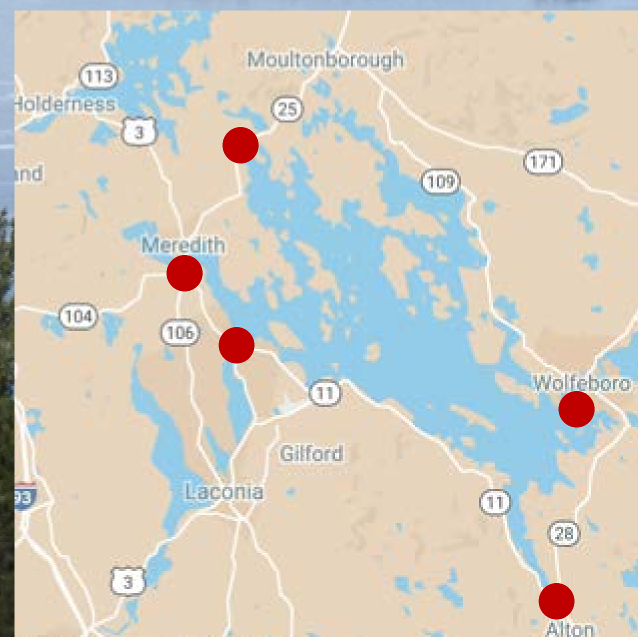


Burakowski et al. in prep

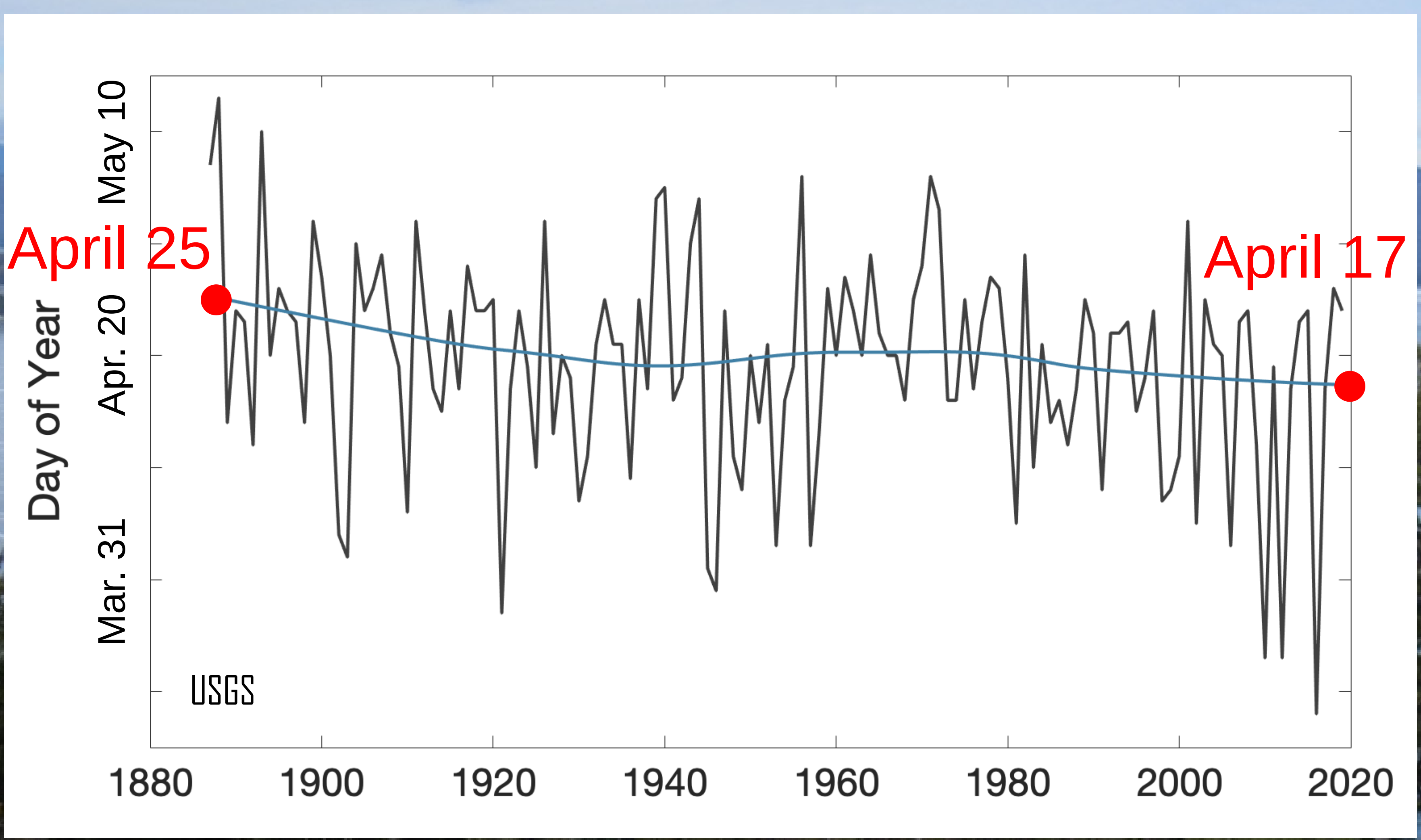

Climate Change Indicators – Lake Ice Out
Photo: Ken Gallager

Climate Change Indicators – Lake Ice Out

Climate Change Indicators – Lake Ice Out



Winnipesaukee Ice Out ~1 week earlier



Hubbard Brook
@HubbardBrookNH

Following

Mirror Lake's official ice-in date is 11/24/2018. The earliest ice-in for the 51-year record is 11/22, which occurred in both 1976 and 1989, making 2018 the earliest ice-in in 29 years! The average ice-in date is 12/7, and the latest ice-in on record is 12/31. Photo: Ian Halm

9:17 AM - 28 Nov 2018

Hubbard Brook
@HubbardBrookNH

Following

UPDATE: Mirror Lake pulled a fast one on us this year. A week after ice-in on November 24, it lost its ice cover. In 51 years of record-keeping, this is a first! Here it is, on November 30, after winds and elevated inlet flows broke up the ice. Stay tuned for more updates!

12:52 PM - 3 Dec 2018

Hubbard Brook
@HubbardBrookNH

Following

As of 12/5, Mirror Lake has iced-in again, making this the new ice-in date for 2018. (Ice-in = 50% or more of the lake is covered by ice.) Photo: Tammy Wooster

11:15 AM - 6 Dec 2018

4 Likes

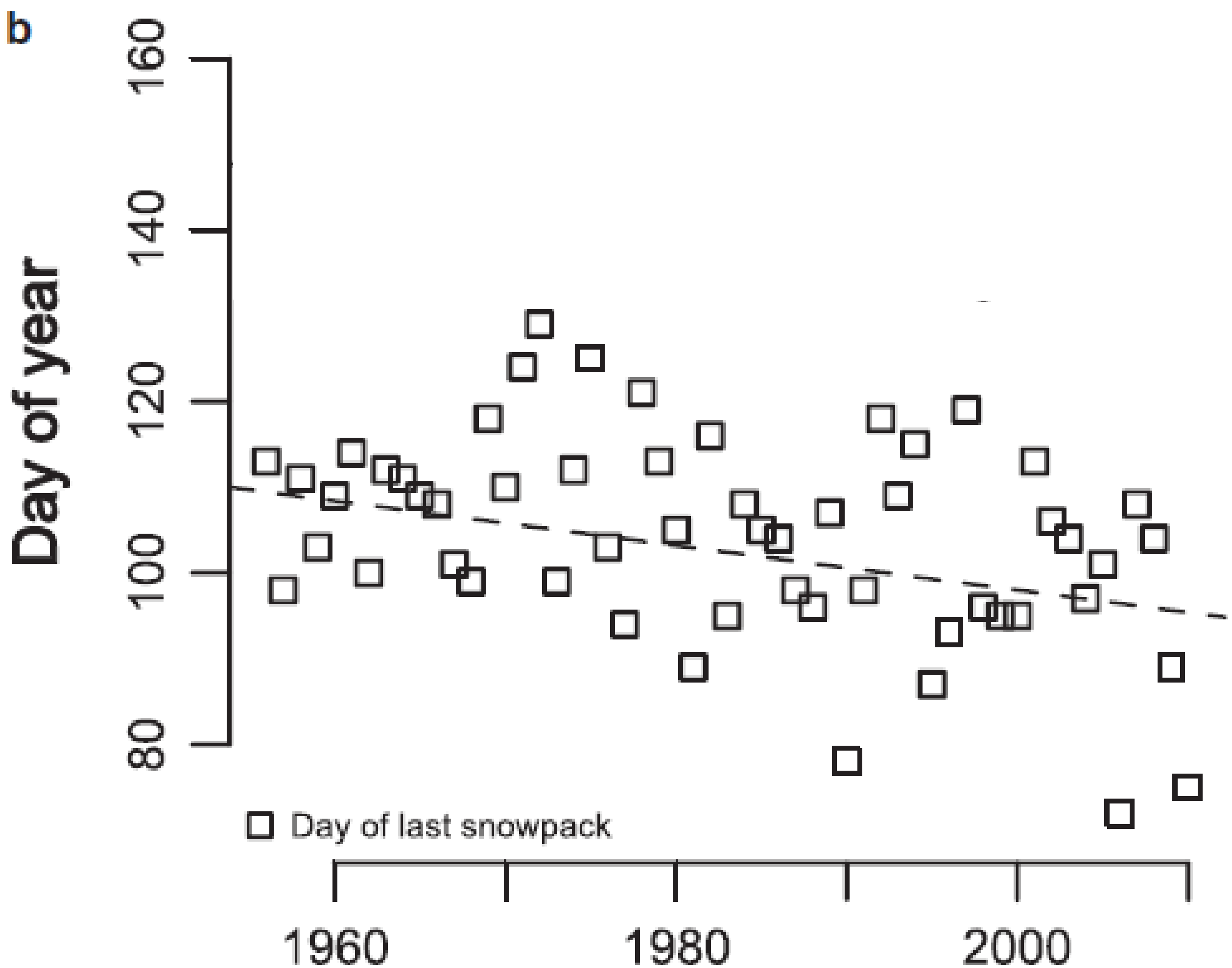
1 4

A Lengthening Vernal Window?

Snowmelt to Canopy Closure

Creed et al. 2015
Contosta et al. 2017

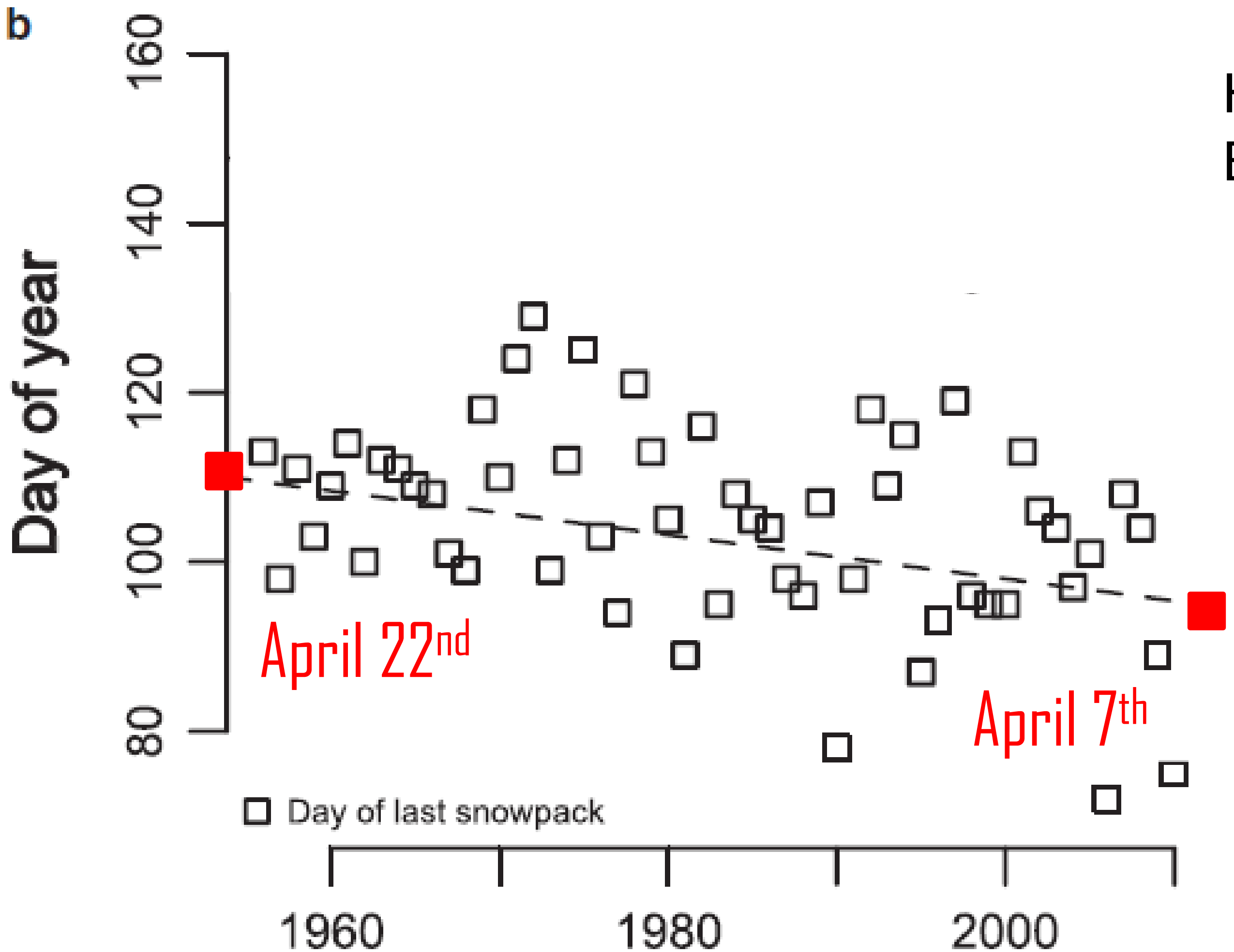
The date of snowpack disappearance at Hubbard Brook NH, 1956-2010.



Hubbard Brook

Groffman et al. 2012

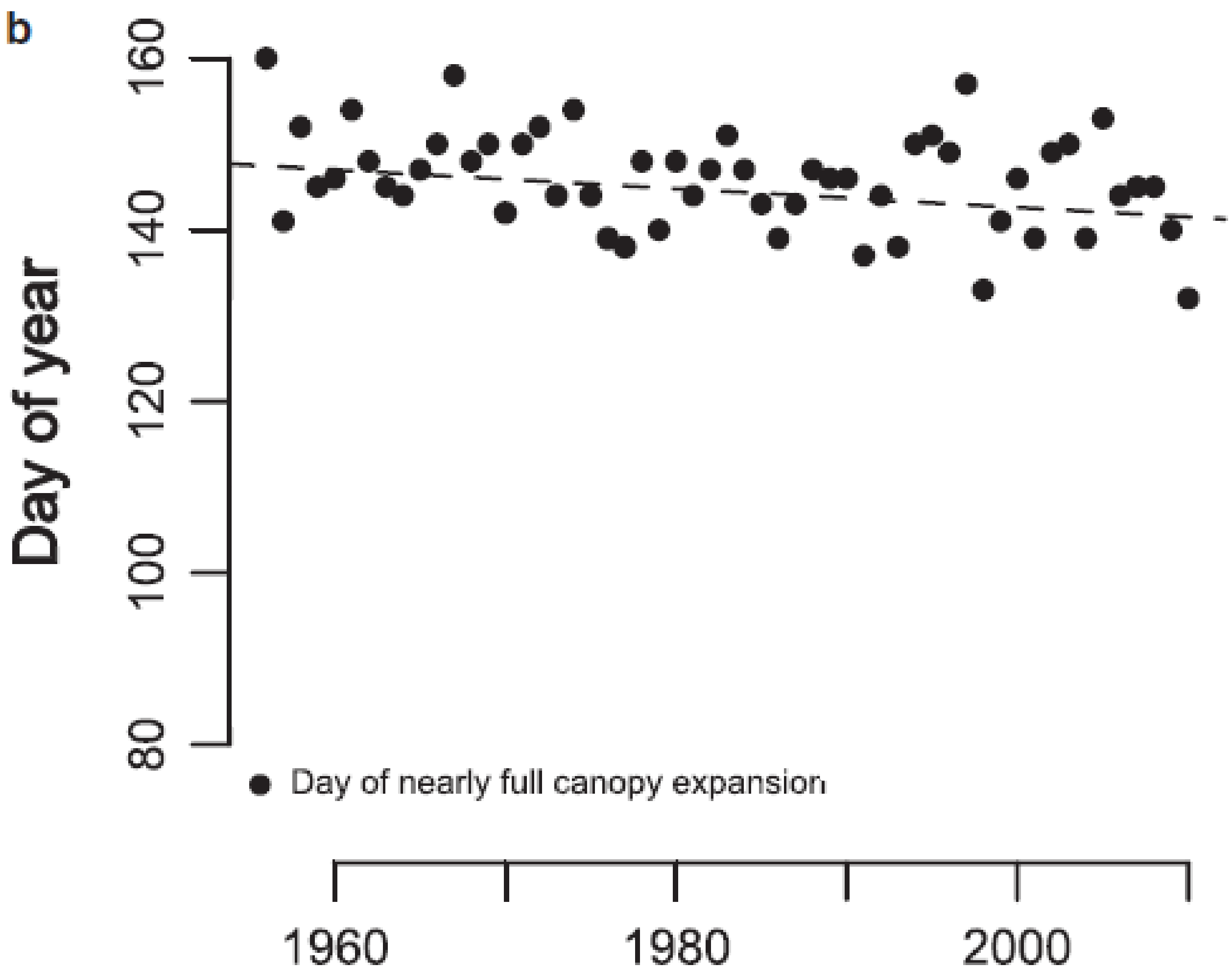
Snowpack disappears ~ 15 days earlier.



Groffman et al. 2012

Earlier snowmelt lengthens the vernal window.

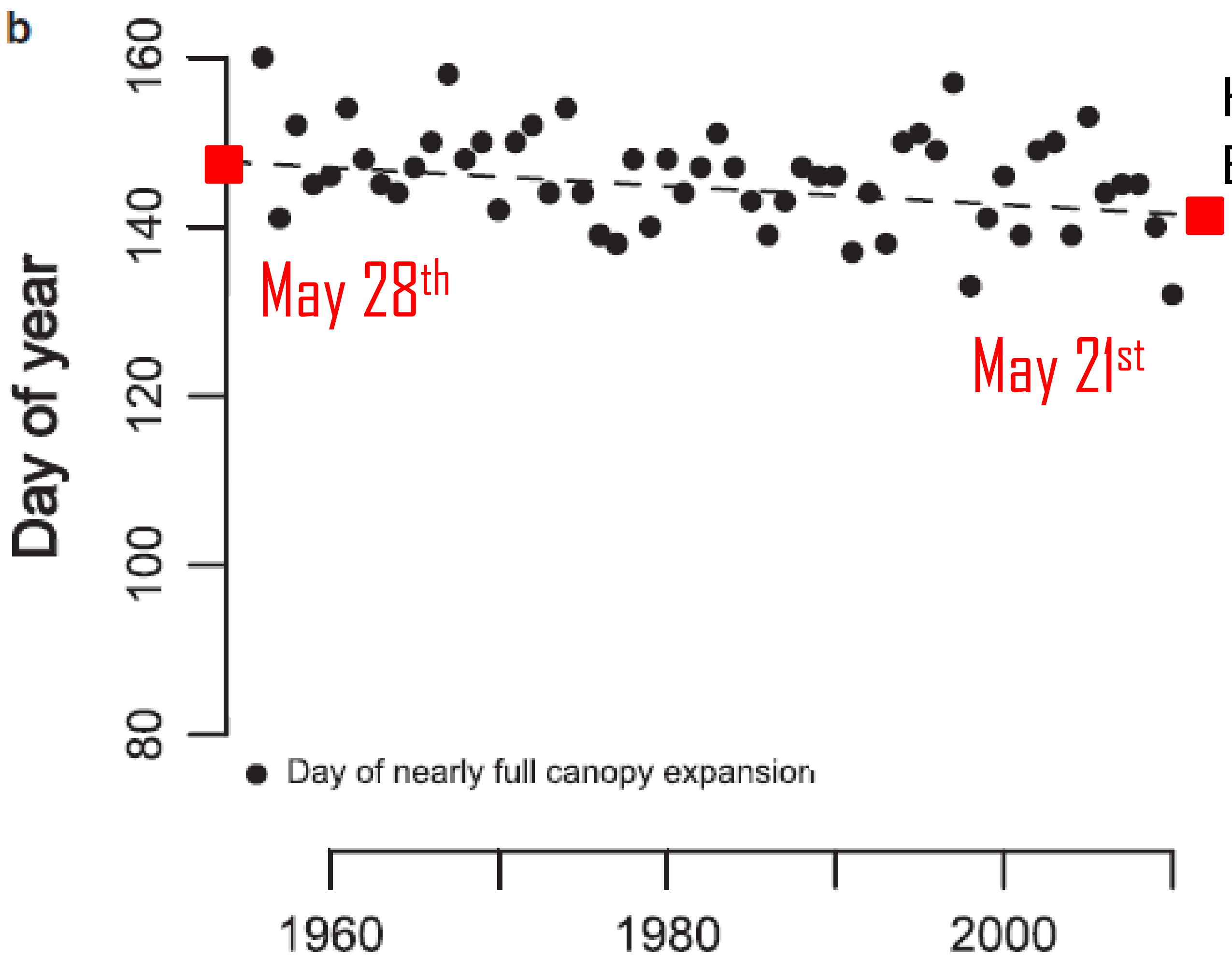
The date of canopy closure at Hubbard Brook NH, 1956-2010.



Hubbard Brook

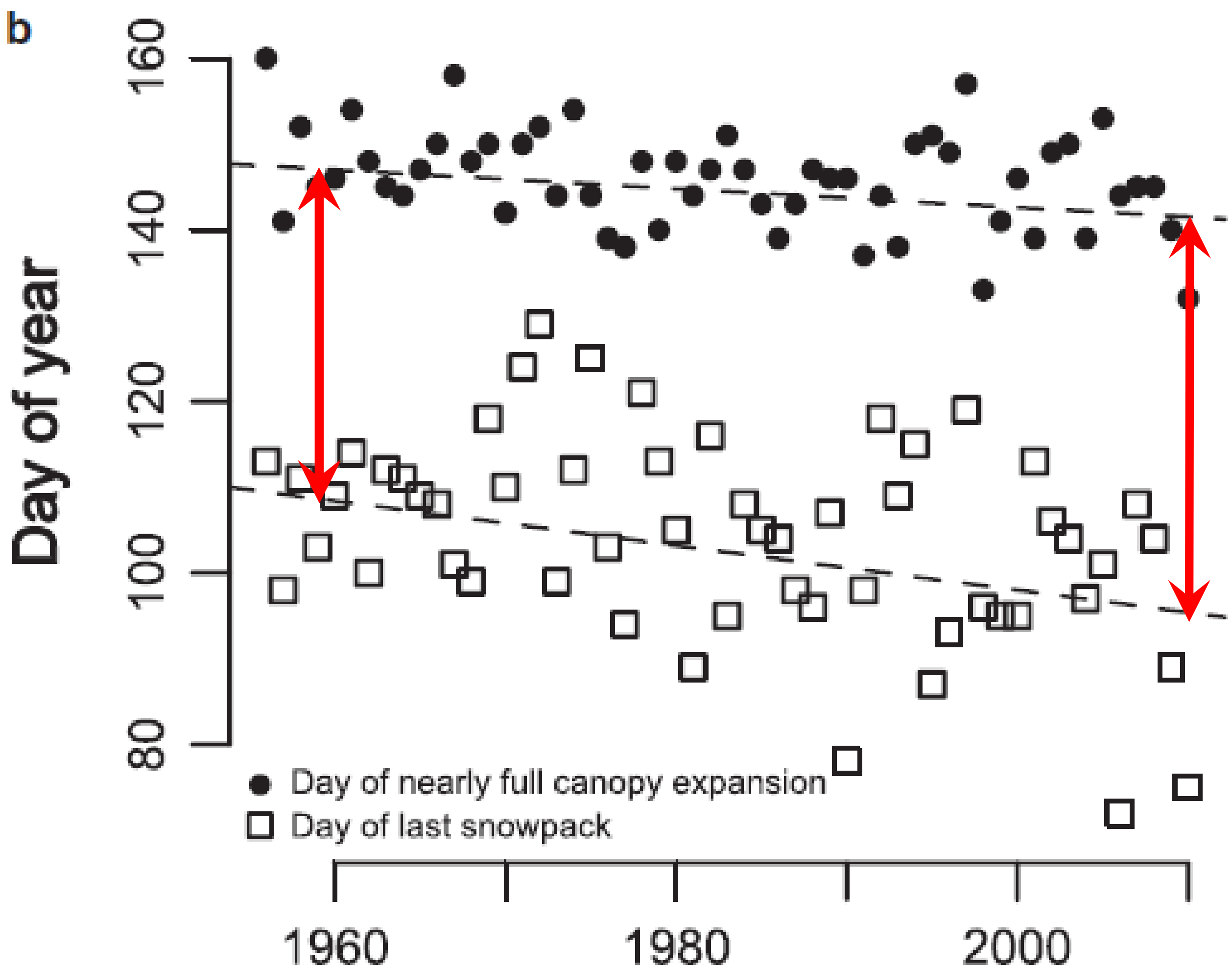
Groffman et al. 2012

Canopy closes ~ 7 days earlier.



Groffman et al. 2012

An overall lengthening of the vernal window, by ~8 days.



Hubbard Brook

Groffman et al. 2012

A longer vernal window could lead to phenological mismatches in timing of key energy, carbon, and water related ecosystem processes.

Energy:
Snowmelt → Snow-free

Carbon:
Snow-free → Budburst

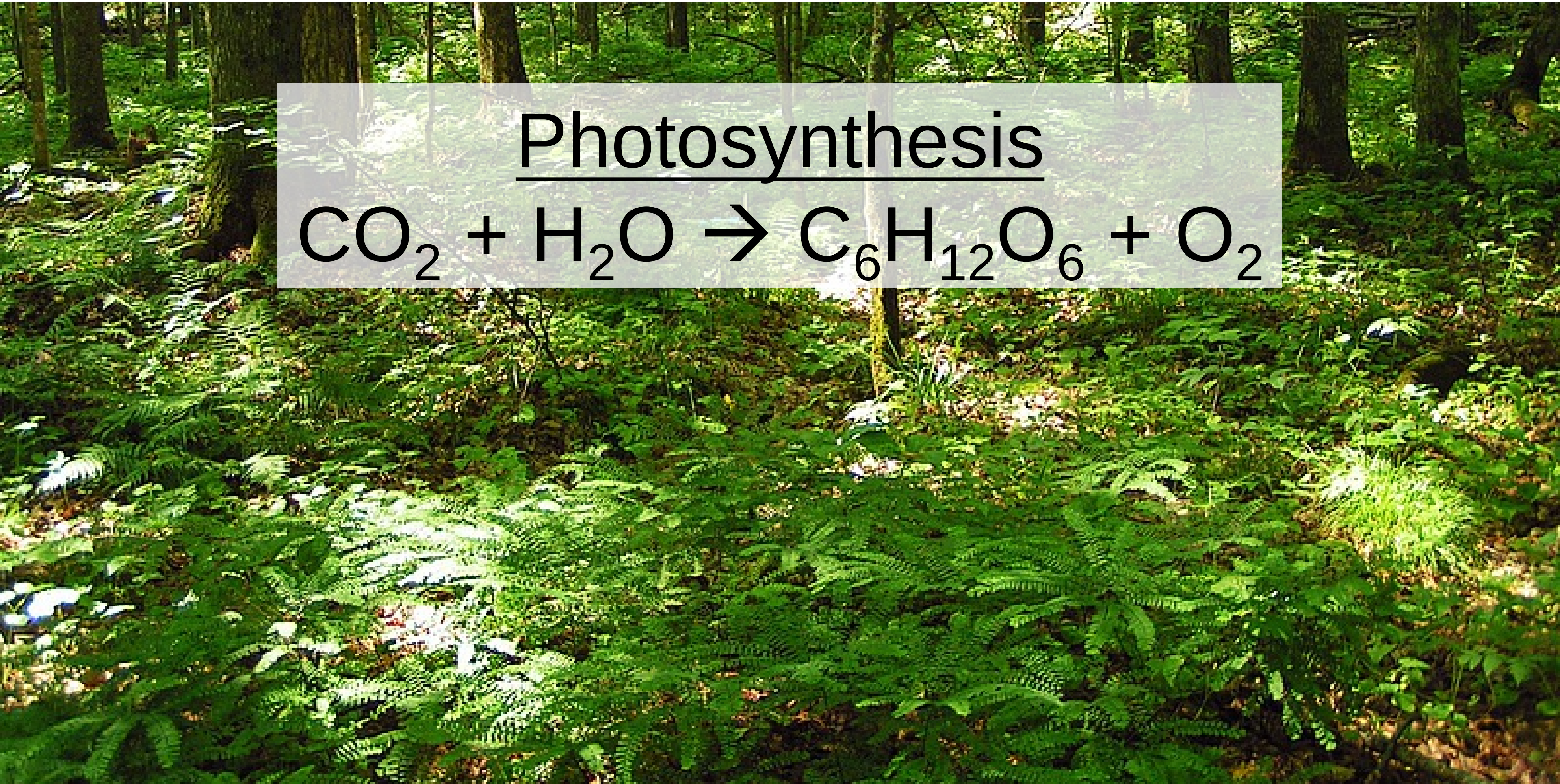
During the snow-free period, soils warm up and microbes start respiring organic matter, releasing carbon dioxide.

Respiration:

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$$

Carbon:
Snow-free → Budburst

Once budburst begins, ecosystem begins to take up carbon dioxide through photosynthesis.



<u>Photosynthesis</u>

$$CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$$

Water:
Snowmelt → Peak streamflow

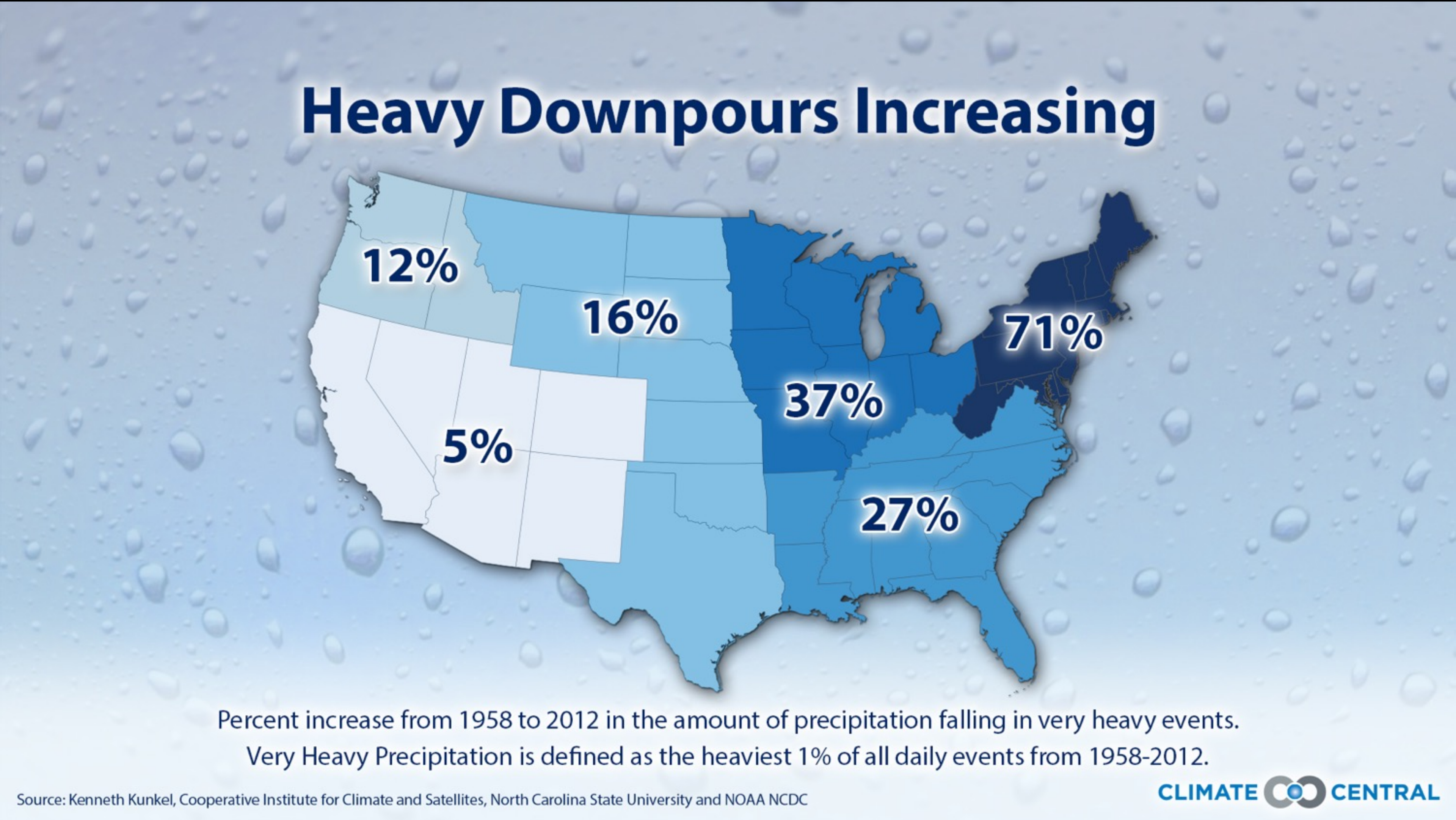
What will the vernal window look like in the future?

What will the vernal window look like in the future?

February 26, 2017
Kingman Farm, Durham, NH

This is the warmest February day ever recorded in Boston. *Boston Globe*

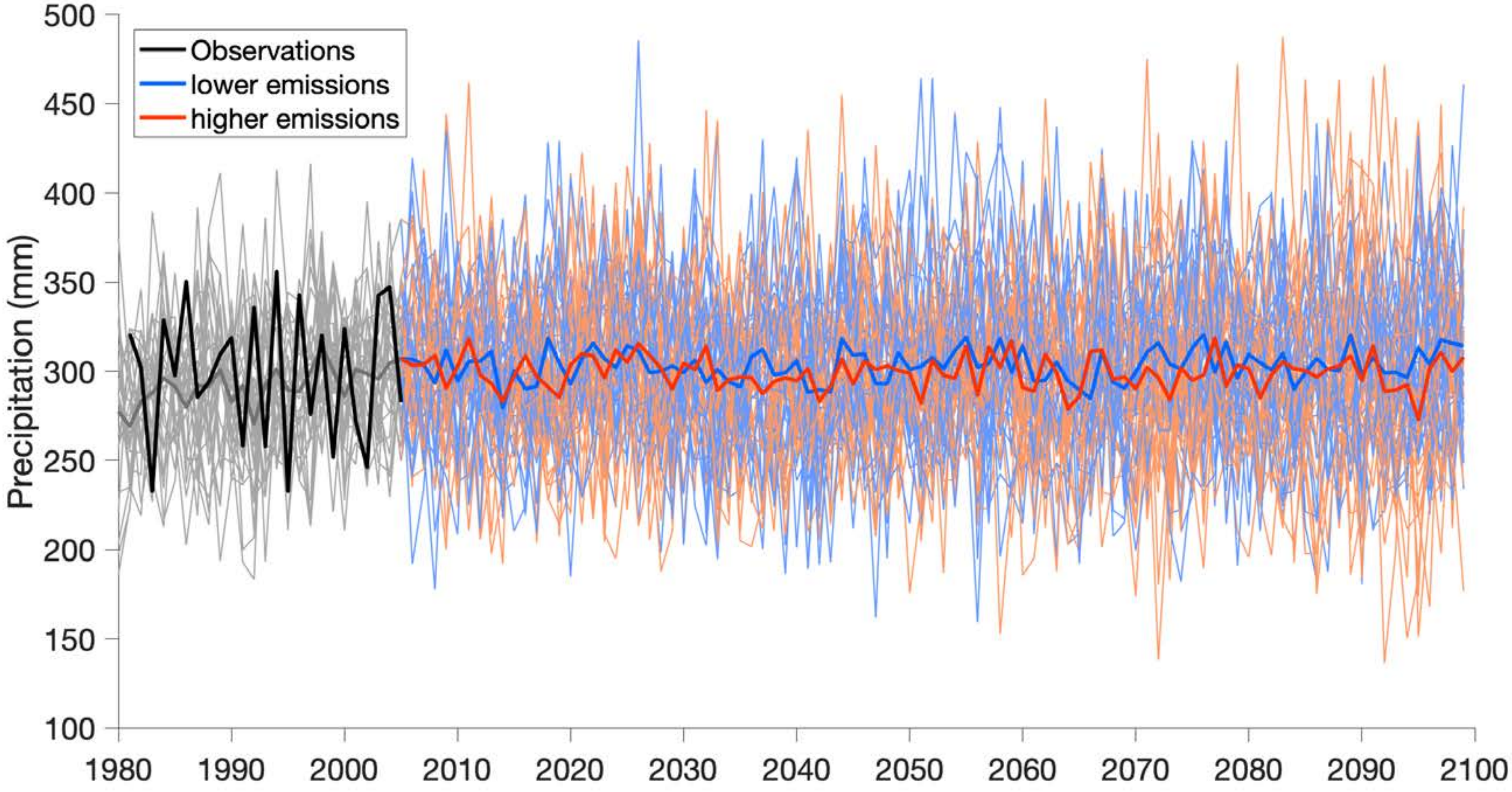
Historical Increase in Extreme Precipitation



Future precipitation trends:

No statistically significant increase in summer precipitation + warmer temperatures → drought

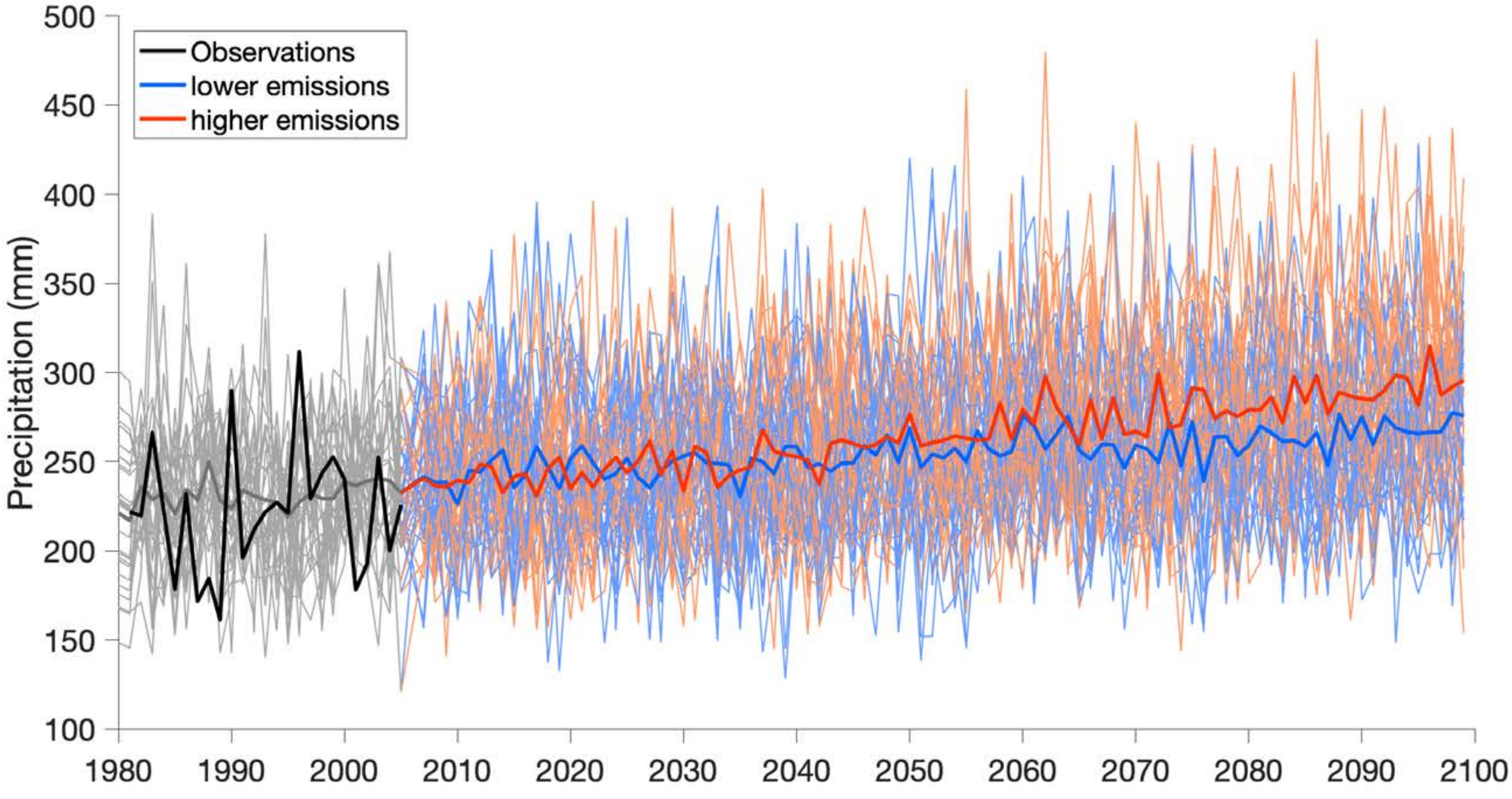
Burakowski et al. in prep



Future precipitation trends:

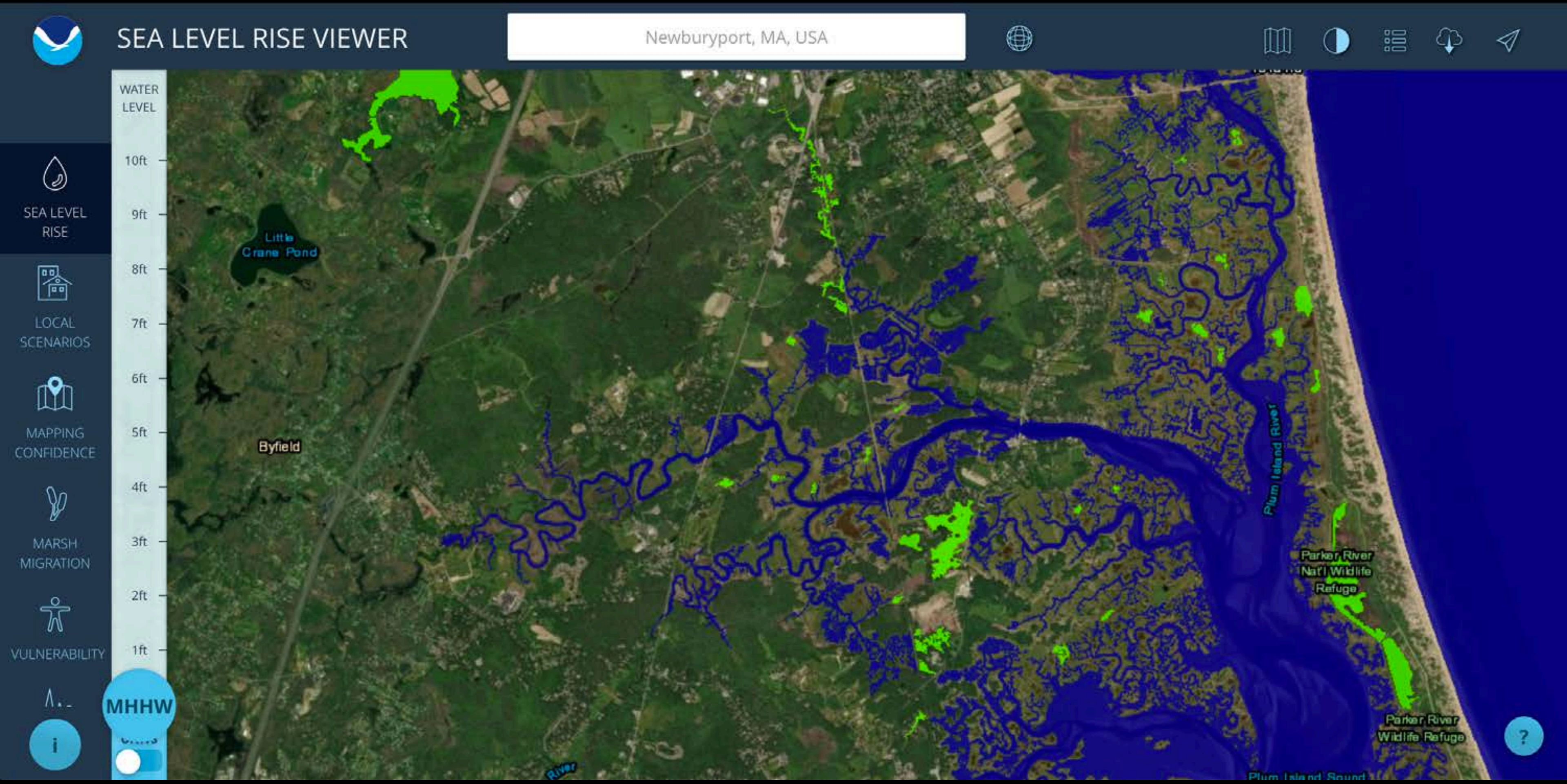
Increase in winter precipitation + warmer temperature → more mid-winter rain or rain-on-snow

Burakowski et al. in prep



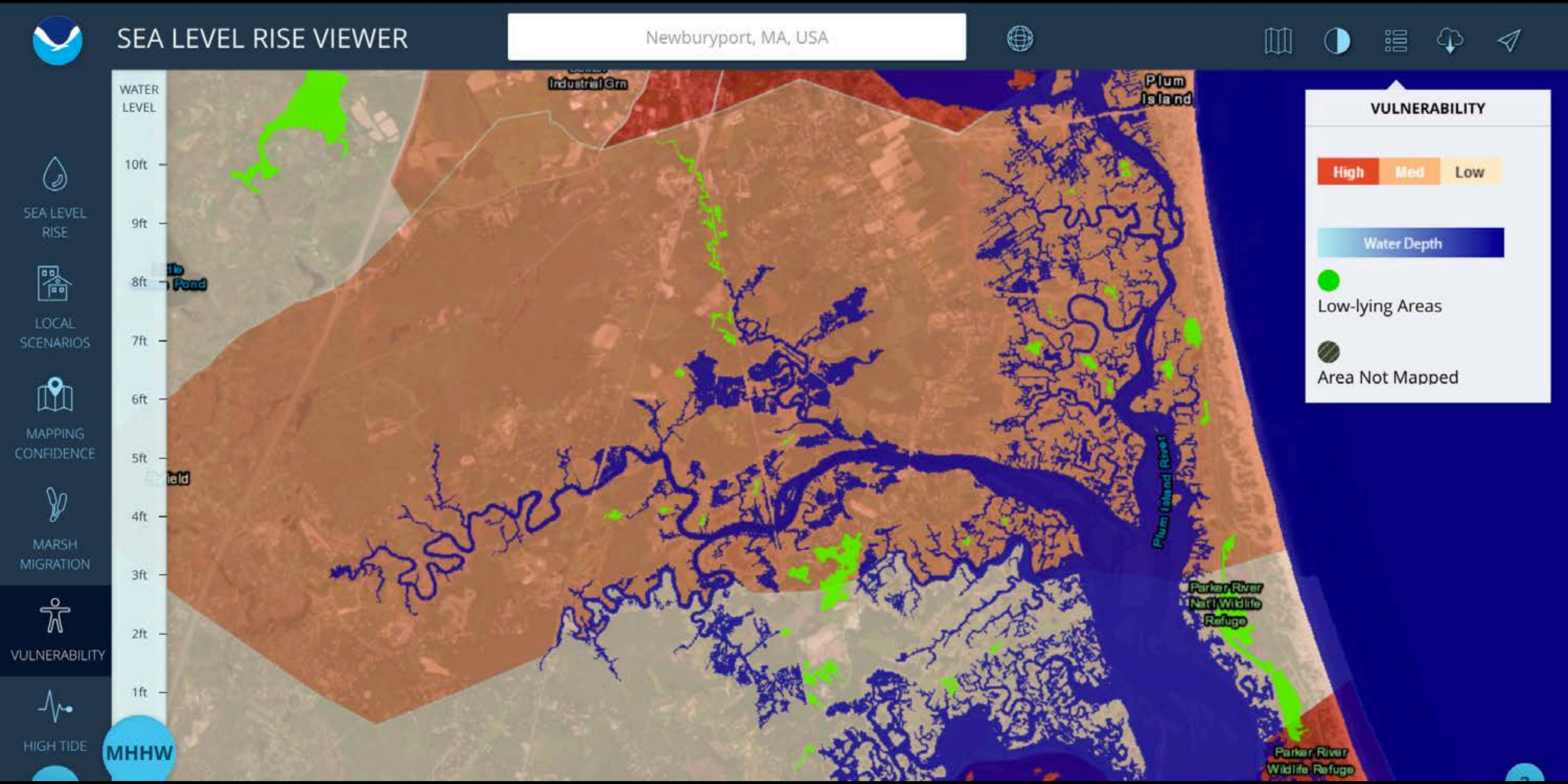
Sea Level Rise

Mean Higher High Water (MHHW)



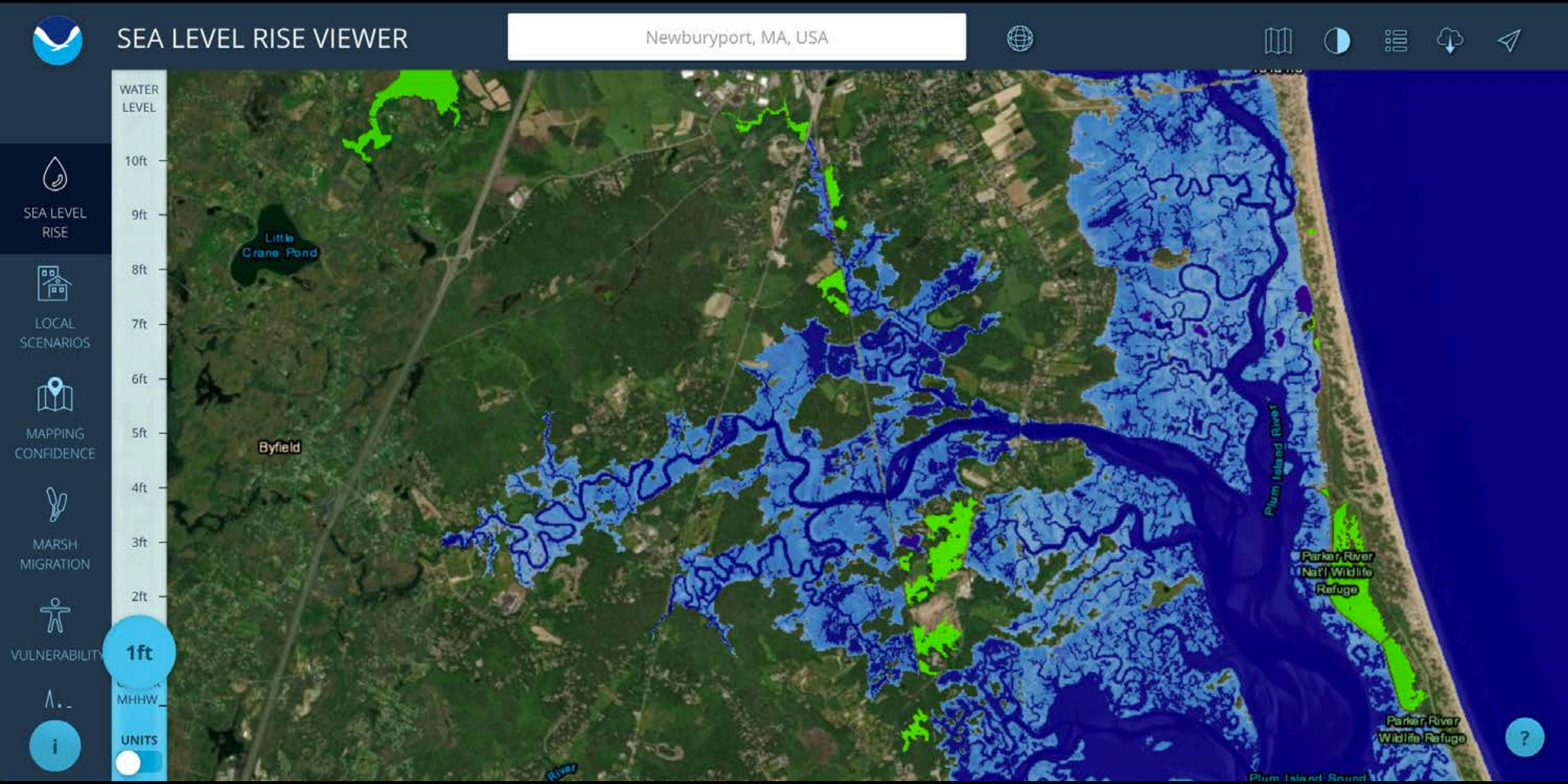
Sea Level Rise

Mean Higher High Water (MHHW)



Sea Level Rise

1-ft of sea level rise



Shapley-Drisco House basement flooding in Portsmouth, NH

Solutions?
Mitigation & Adaptation

Climate Change is the Innovation Opportunity of the 21st Century

1. Price on carbon
2. Promote energy efficiency & renewables
3. Conserve ecosystems (key carbon sinks)
4. Transition to lower carbon food system
5. Adapt to unavoidable climate change