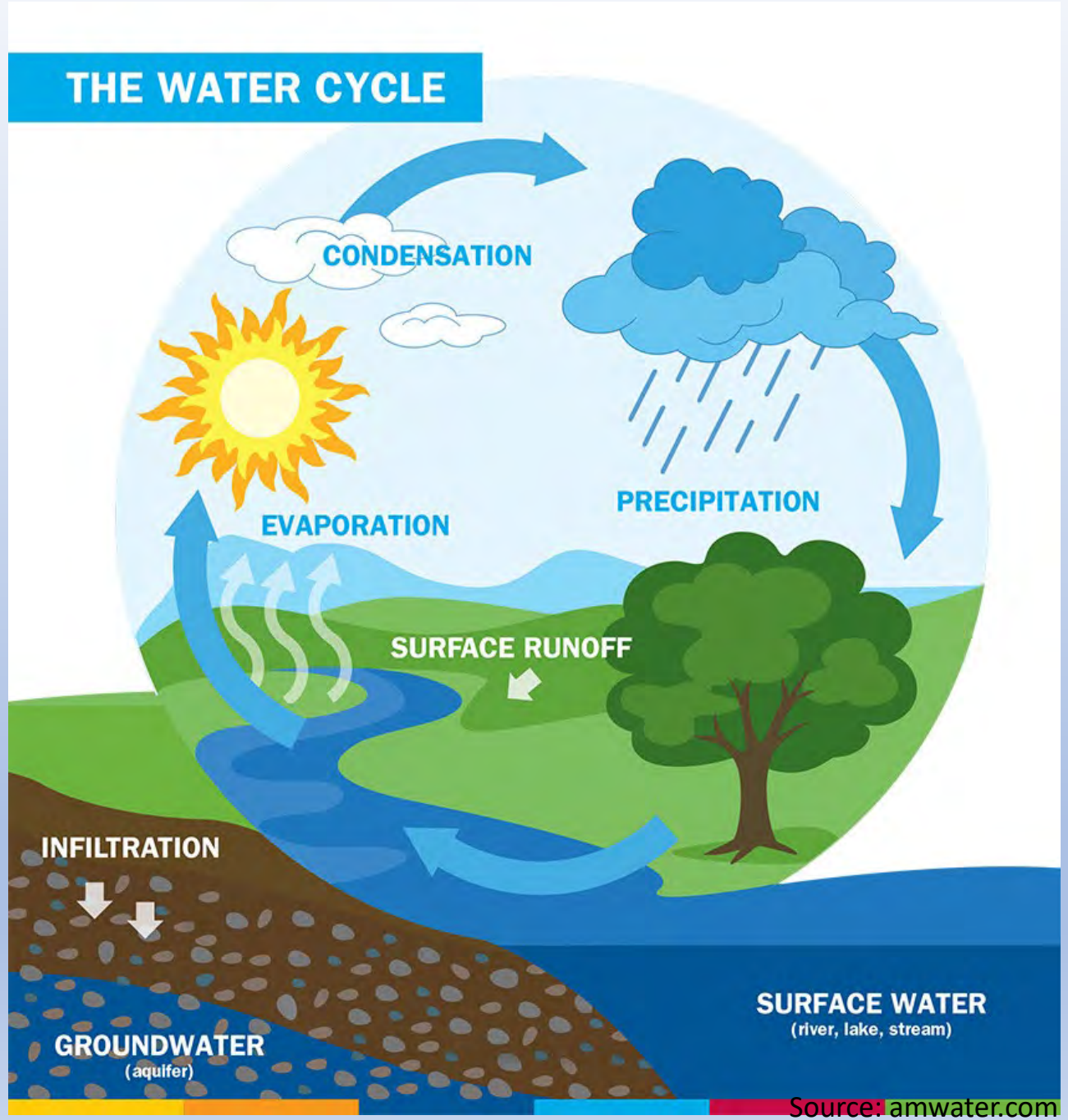
Freshwater Monitoring, Science, and Management at Cape Cod National Seashore

Sophia Fox, Ph.D., Aquatic Ecologist

Kelly Medeiros, M.S., Natural Resource Specialist

The Freshwater Cycle



Source: amwater.com

- Freshwater is cycled through a complex system from the earth's surface to the atmosphere and back
- This system of freshwater is heavily inter-connected through 3 main pools

Precipitation – rain, water vapor, clouds

Groundwater – sole source aquifer

Surface water – ponds, lakes, streams

Freshwater Monitoring at CACO

- Measure 3 Freshwater pools: Precipitation, Groundwater, Surface water

- Atmosphere – rain, water vapor and clouds - Precipitation quantity & quality

Air Quality Monitoring – 1982-present (weekly, year-round)

- Groundwater – sole source aquifer - Groundwater quantity

Hydrologic Monitoring – 1999-present (monthly, year-round)

- Surface water – ponds, lakes, streams - Surface water quantity & quality

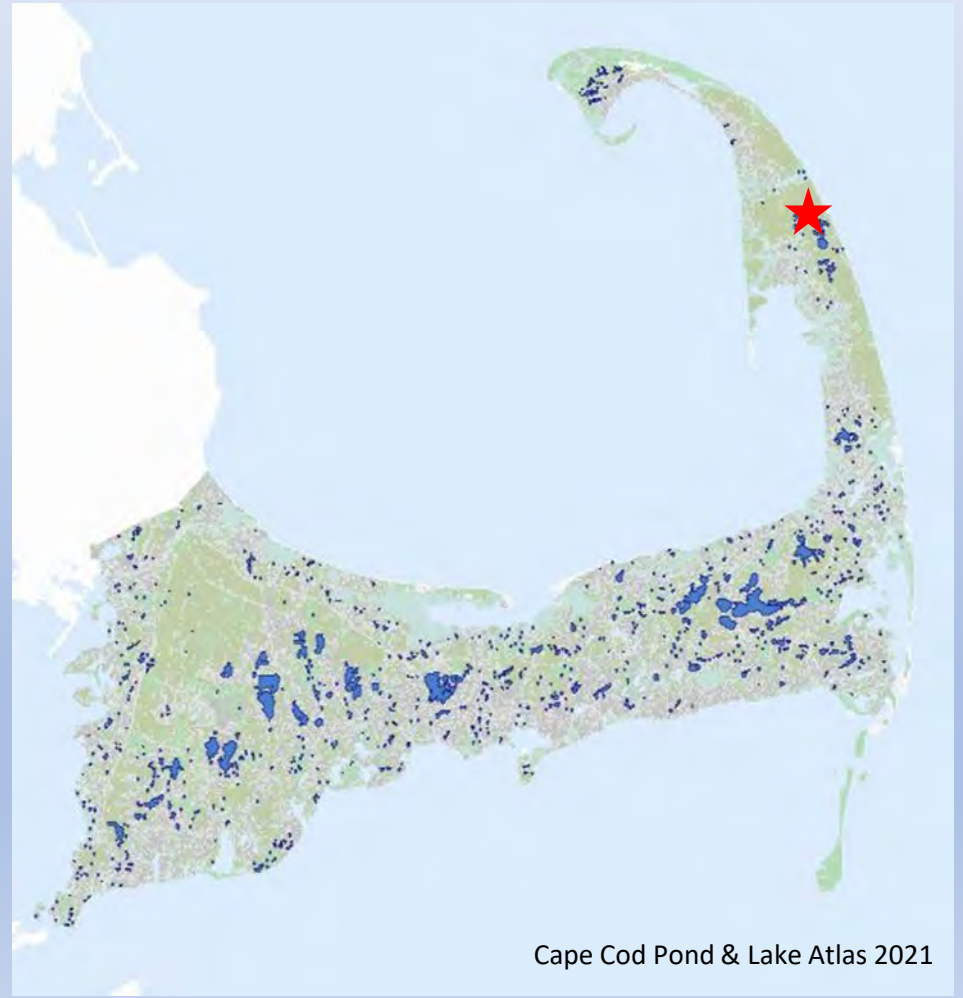
Hydrologic Monitoring

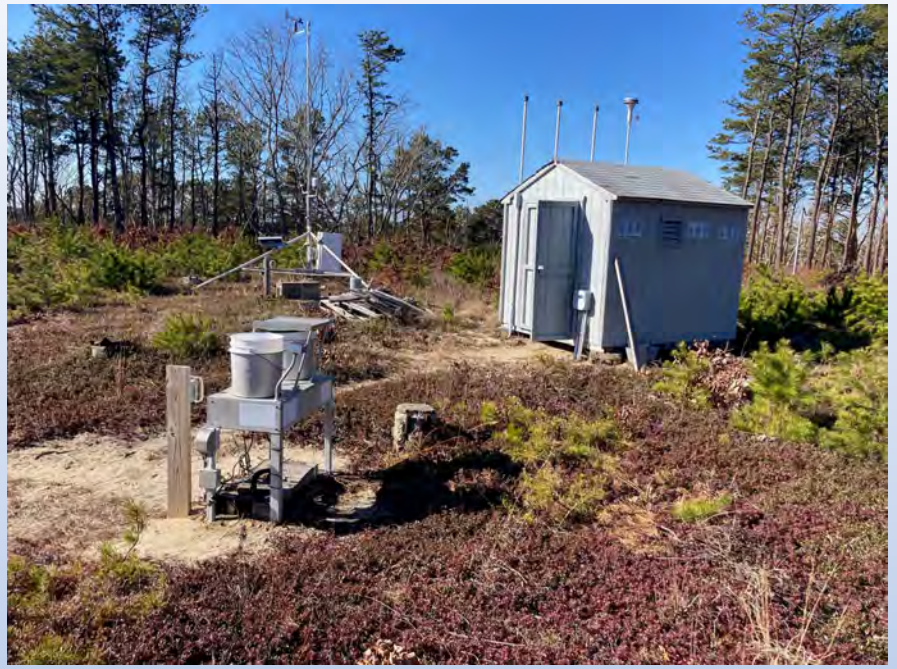
Kettle Pond Water Quality Monitoring – 1970s-present (bi-weekly, Mar-Dec)

Precipitation Monitoring at CACO

- Atmosphere – Precipitation quantity & quality

Air Quality Monitoring – 1982-present (weekly, year-round)





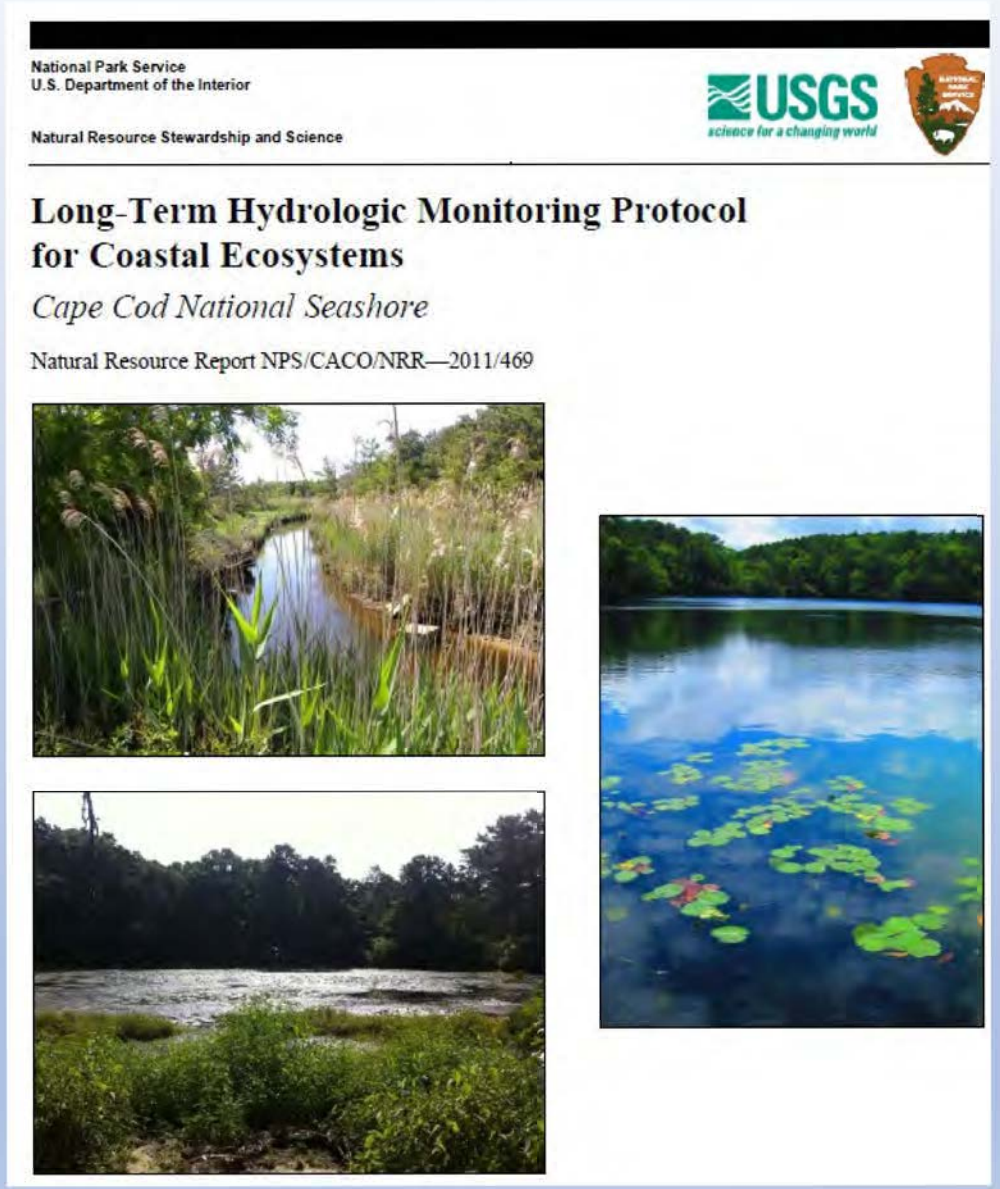
- North Truro, Mitre Site

- National Atmospheric Deposition Program and Mercury Deposition
- Goal: To understand impacts of air pollution and climate
- Measure: amount of rain and rain chemistry (byproducts of combustion, pH, mercury, etc.)

Groundwater/Surface Water Monitoring

- Groundwater and surface water quantity

Hydrologic Monitoring – 1999-present
(monthly, year-round)



National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

USGS science for a changing world

Long-Term Hydrologic Monitoring Protocol for Coastal Ecosystems

Cape Cod National Seashore

Natural Resource Report NPS/CACO/NRR—2011/469

Groundwater/Surface Water Monitoring

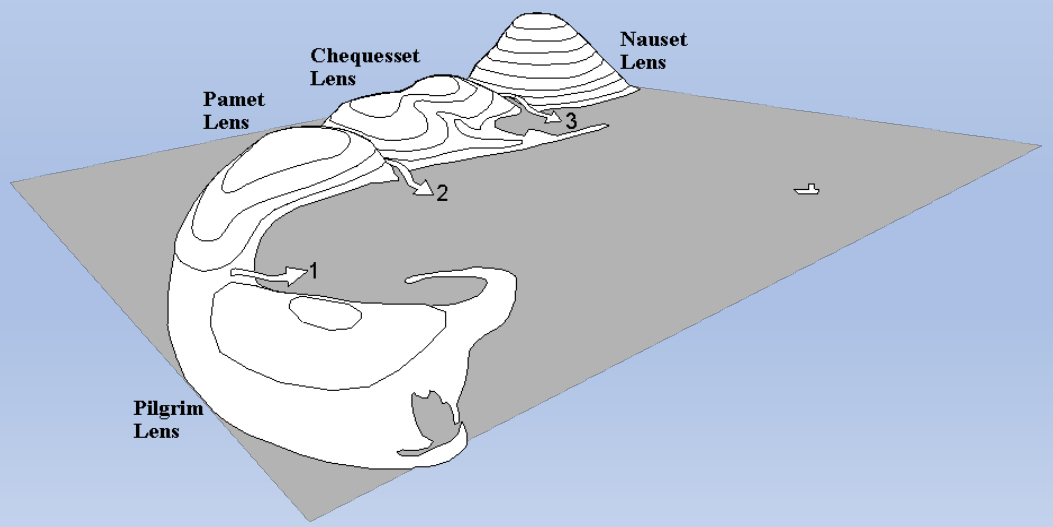
- Groundwater and surface water quantity

Hydrologic Monitoring – 1999-present
(monthly, year-round)

- Goal: To understand agents of hydrologic change, e.g., urbanization, climate, and sea level rise
- Measure: groundwater and pond water levels

18 Observation wells

12 ponds



Surface Water Monitoring at CACO

Surface water quality – ponds & lakes

Kettle Pond Water Quality Monitoring – 1970s-present (bi-weekly, Mar-Dec)

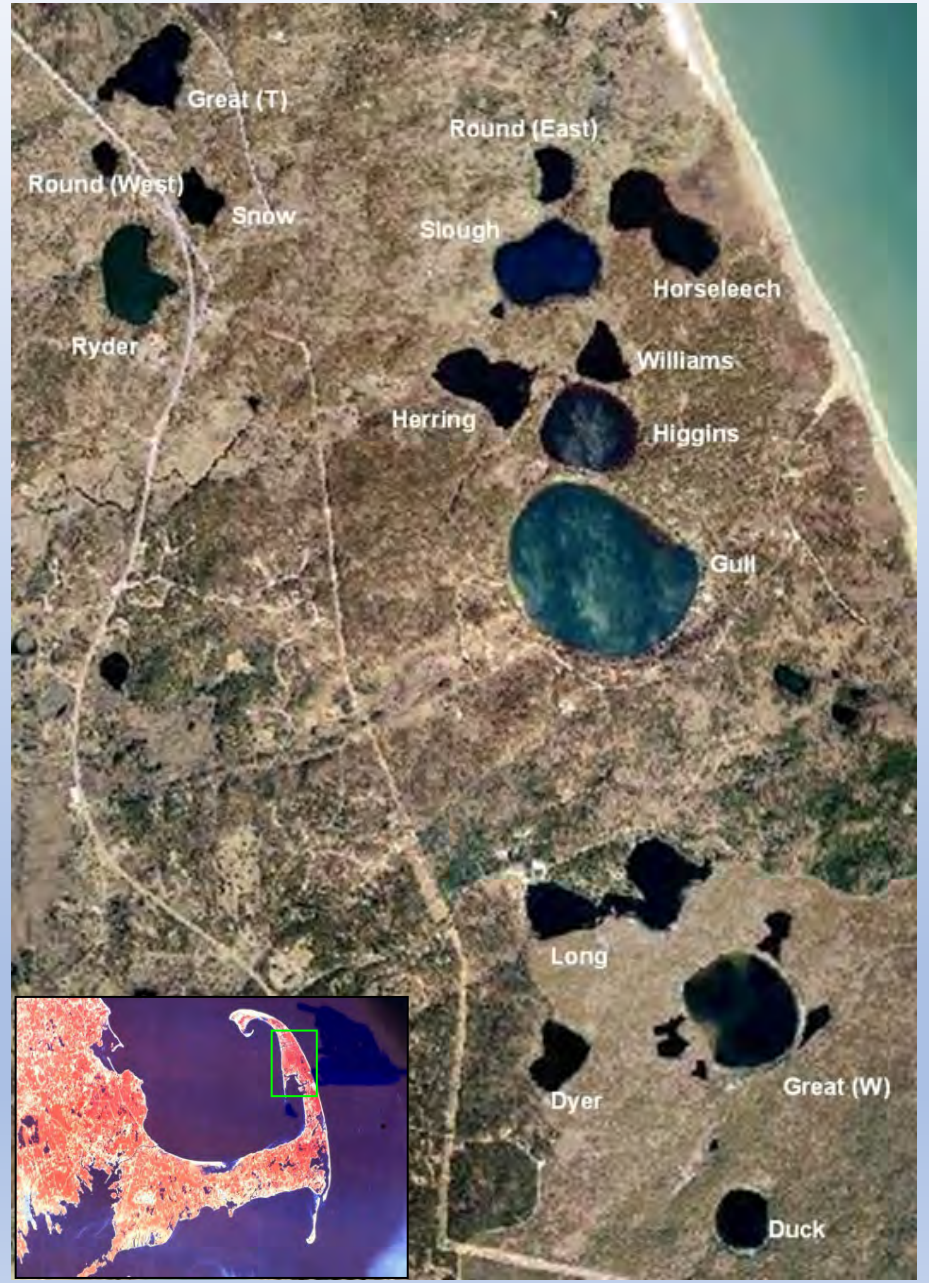
- Goal: To assess trends in water quality, and understand pond processes in a changing environment
- Measure: pond physical, biological, and chemical components

20 ponds -

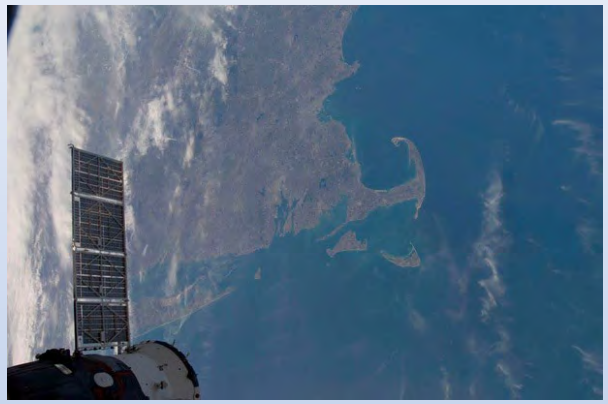
temperature, pH,

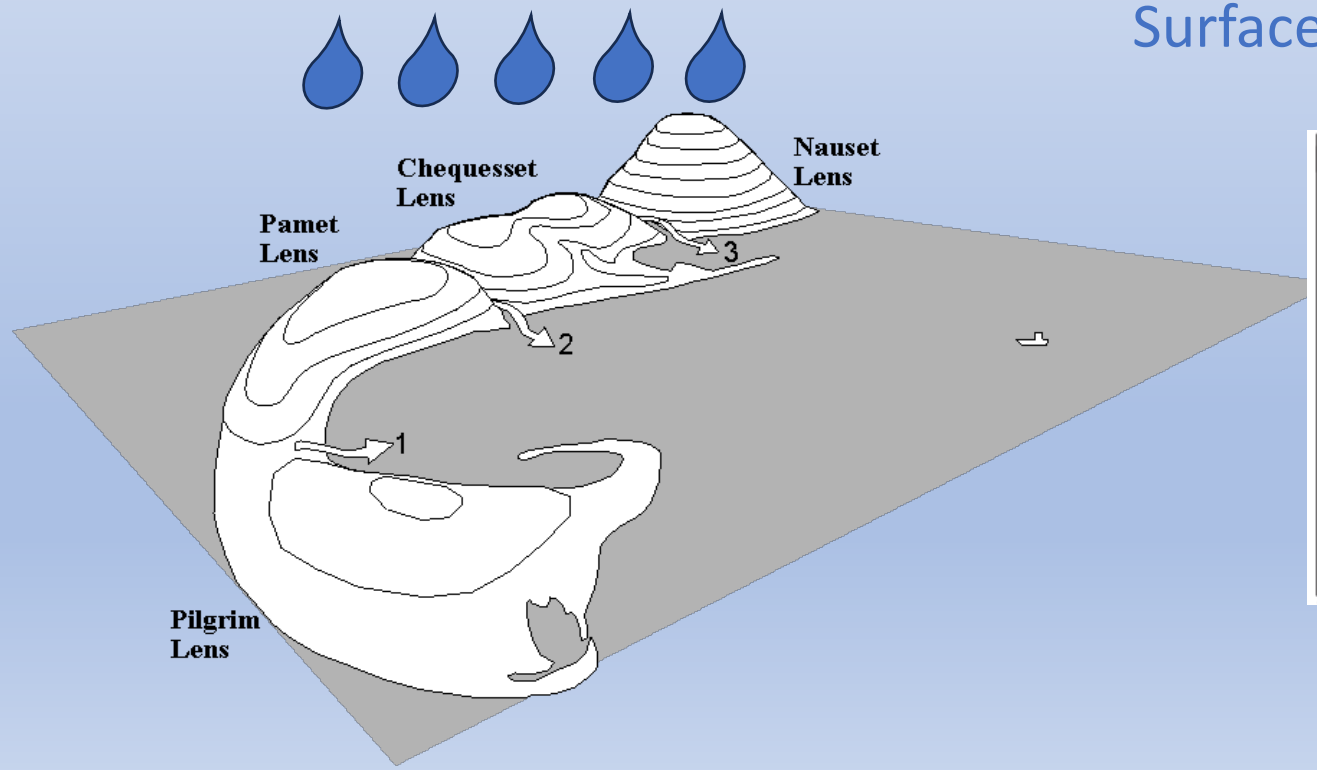
oxygen, light, nutrients,

phytoplankton



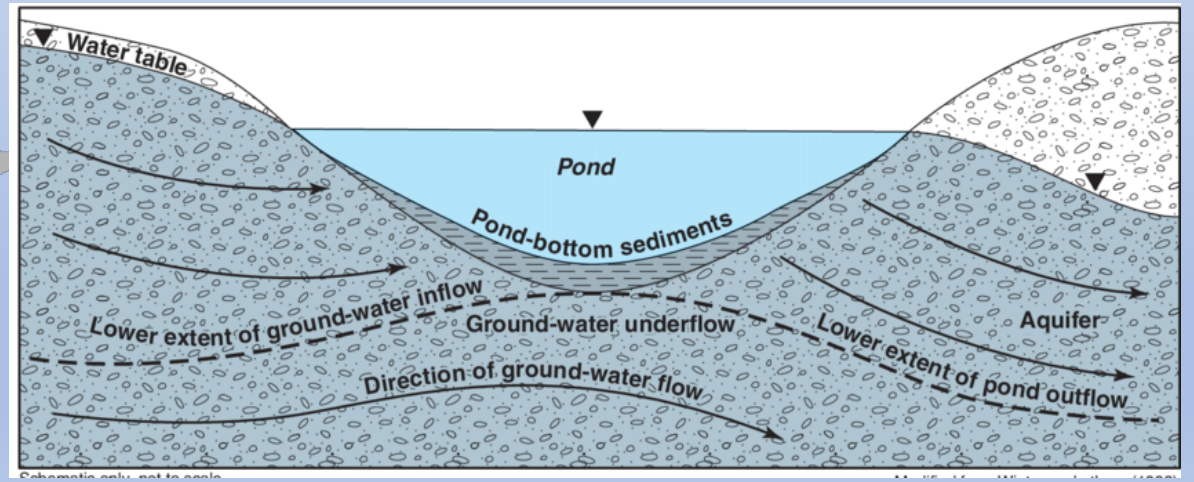
Cape Cod National Seashore Science



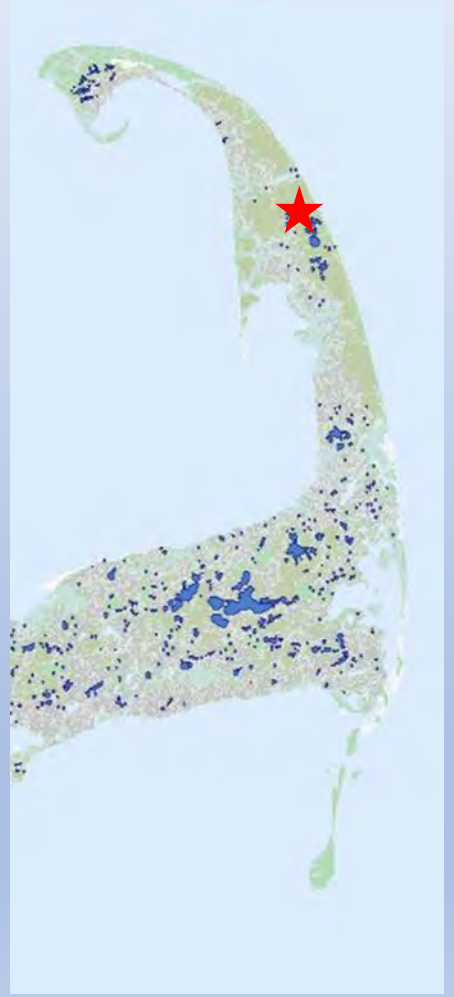


- Understanding the inter-connected freshwater system at CACO with 3 long-term monitoring programs

Precipitation – water vapor, clouds
Groundwater – sole source aquifer
Surface water – ponds, lakes, streams

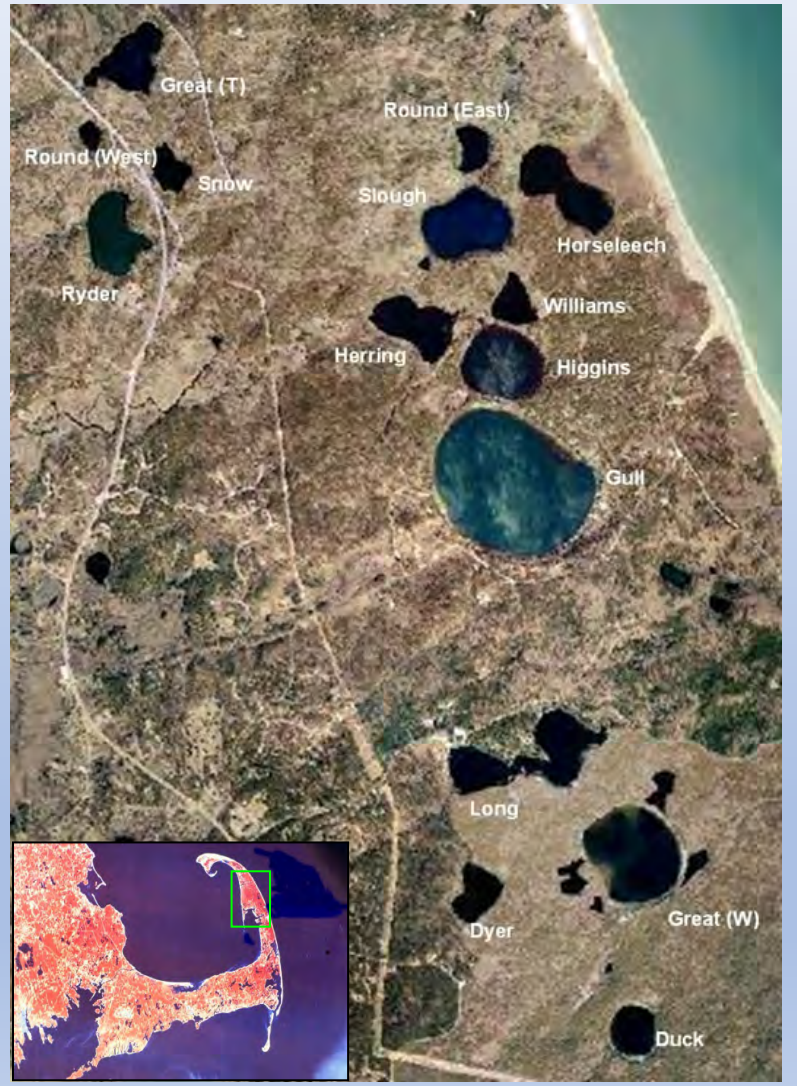


Cape Cod National Seashore Science



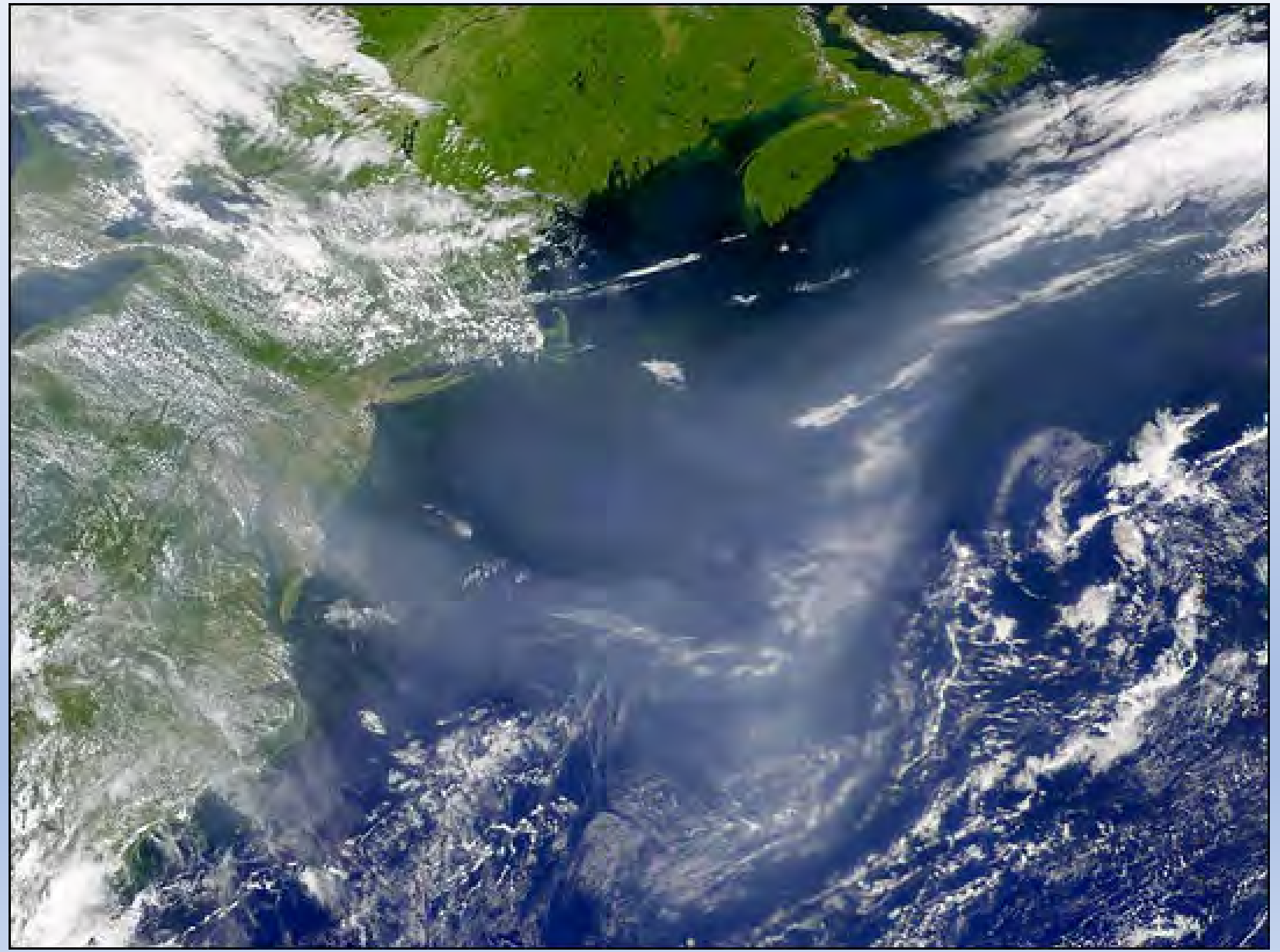
Precipitation quantity & quality

Groundwater and surface water quantity

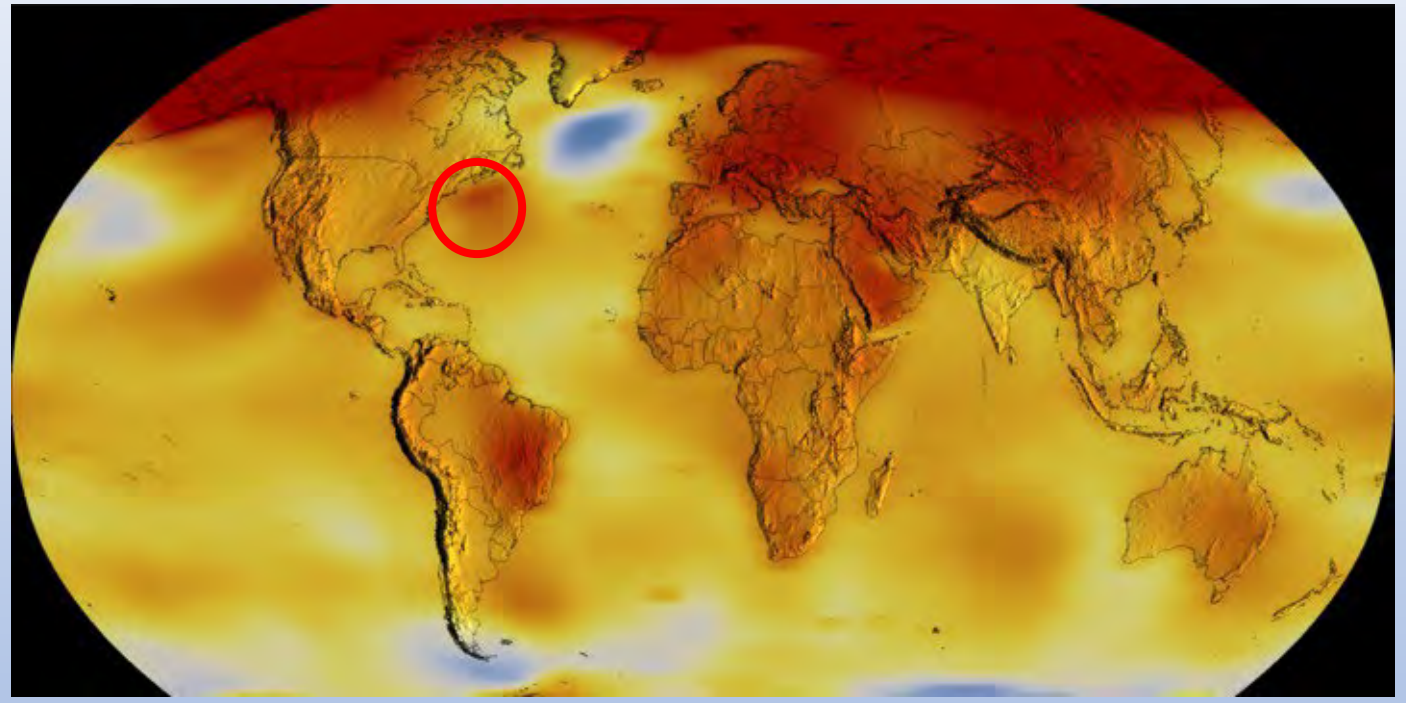


Surface water quality

Atmospheric changes from industrialization



Impacts of atmospheric changes from industrialization



https://climate.nasa.gov/vital-signs/global-temperature/

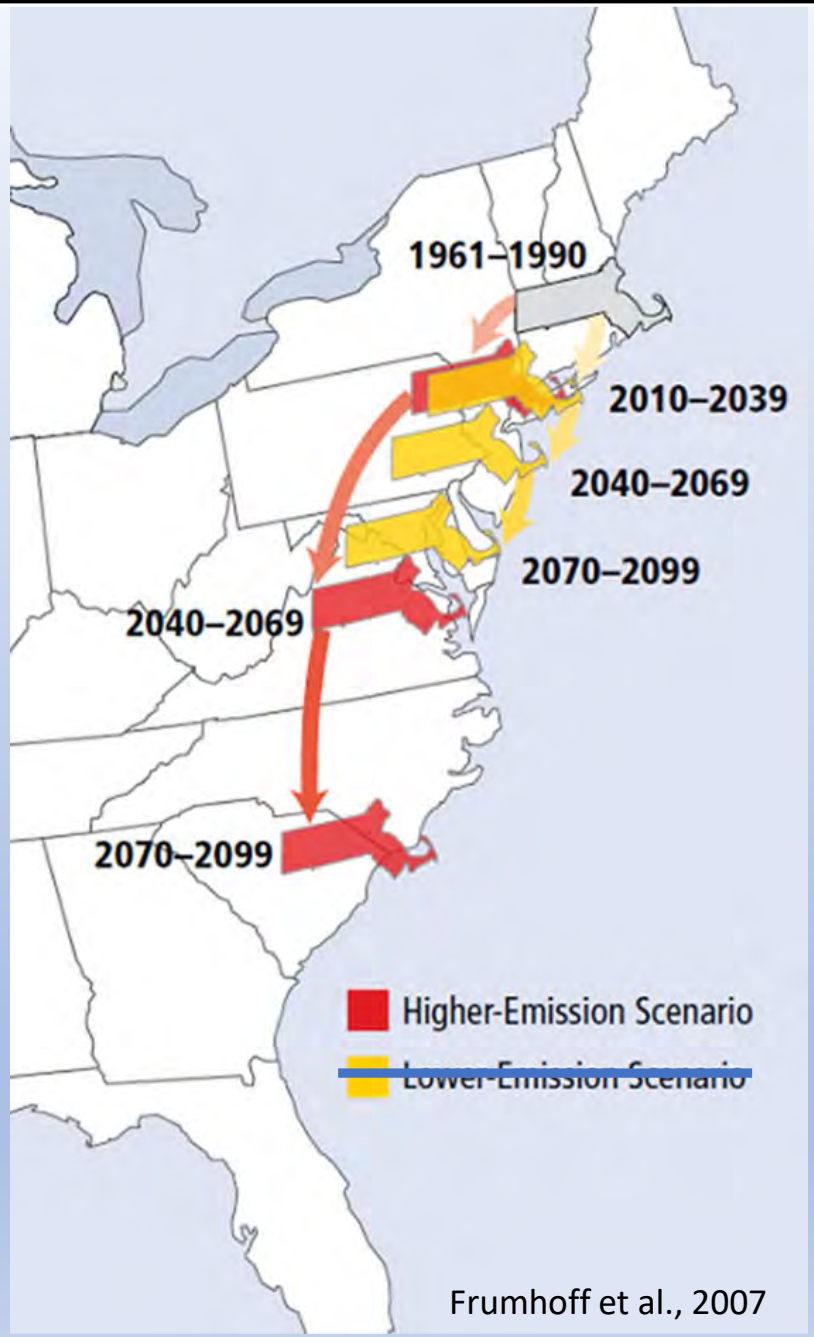
- Due to high accumulation of GHGs, Earth's surface temperatures have increased
- Most of the earth is warmer than average, with 2020, 2021, 2022, & 2023 being the hottest on record

Increasing Temperatures and Shifting Climates

- Massachusetts climate shift towards southern US

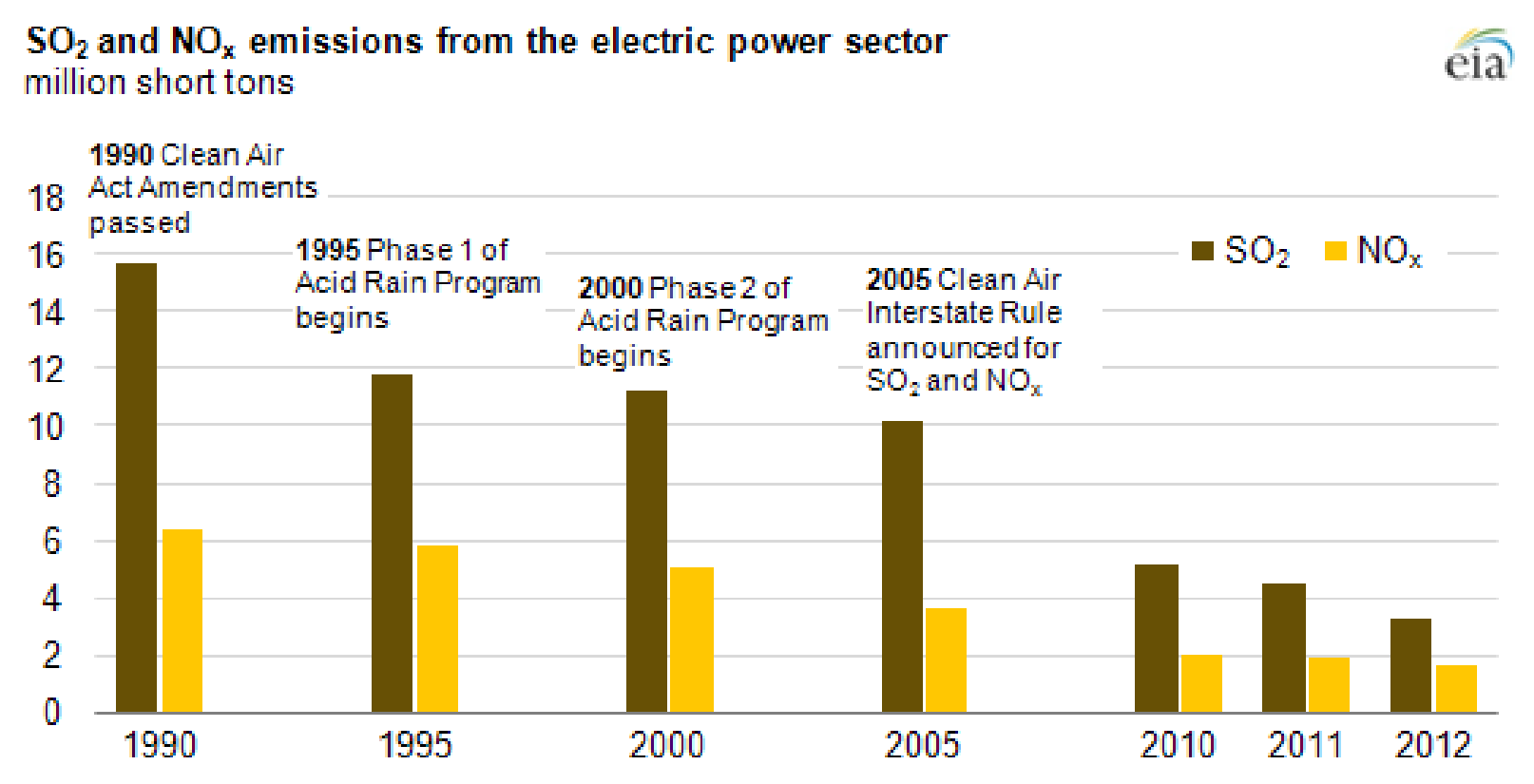
- Lower-Emission scenario from IPCC (Intergovernmental Panel on Climate Change) – no longer likely in 2024

- Modeling heat index for higher-emission scenario, MA feels like SC by 2100



Frumhoff et al., 2007

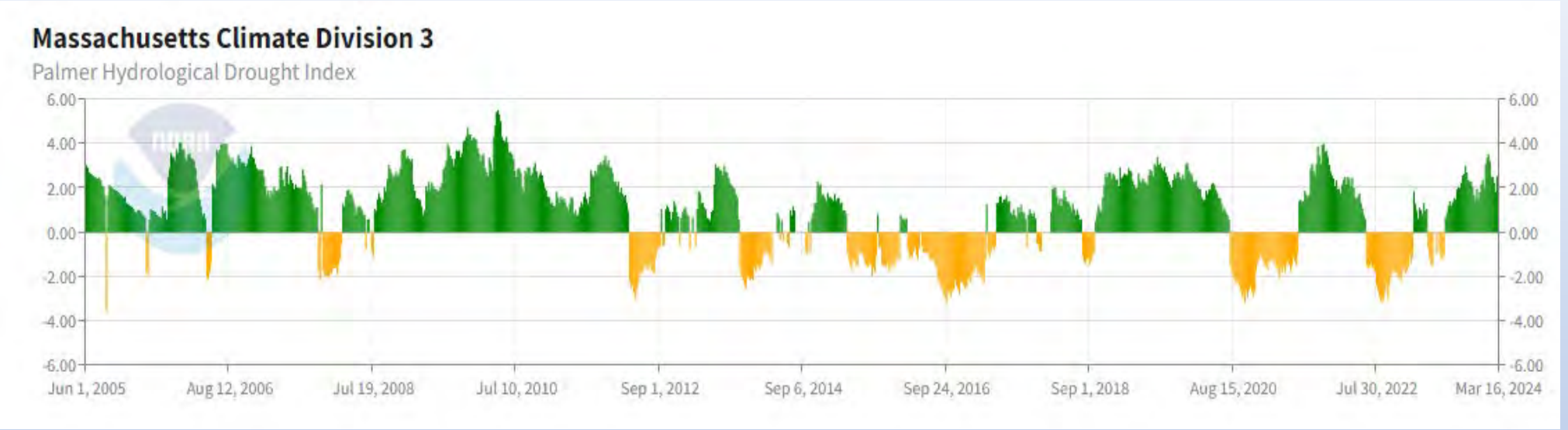
Atmospheric changes from industrialization



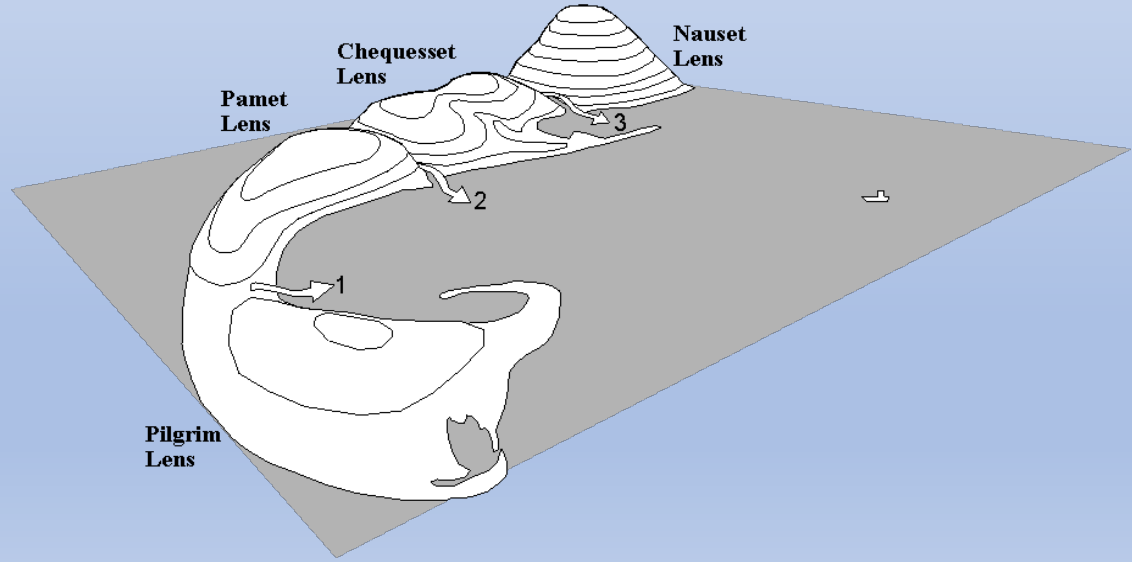
USEIA; USEPA

- Emission regulations in 1990s to control air pollution and acid rain
- Led to declines in sulfur and nitrogen emissions (acidic compounds) over the last 3 decades

Increasing Temperatures and Shifting Climates



- Drier than normal periods are indicated by a negative value of the PHDI and plot in yellow
- More dry periods in last decade
- Indication of changing precipitation inputs to groundwater lenses as rainfall recharge

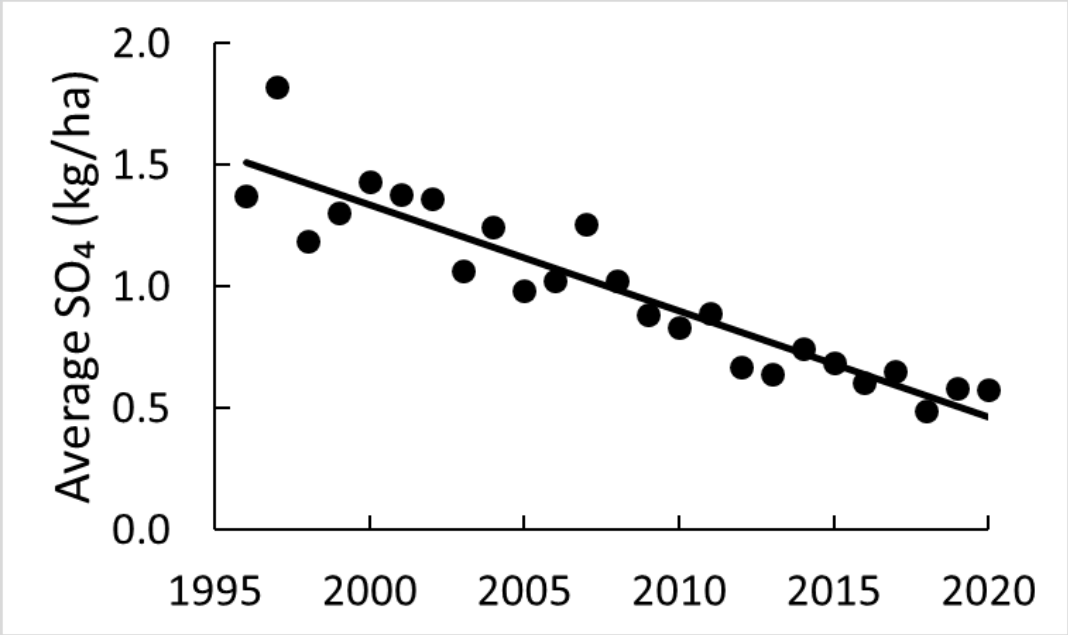


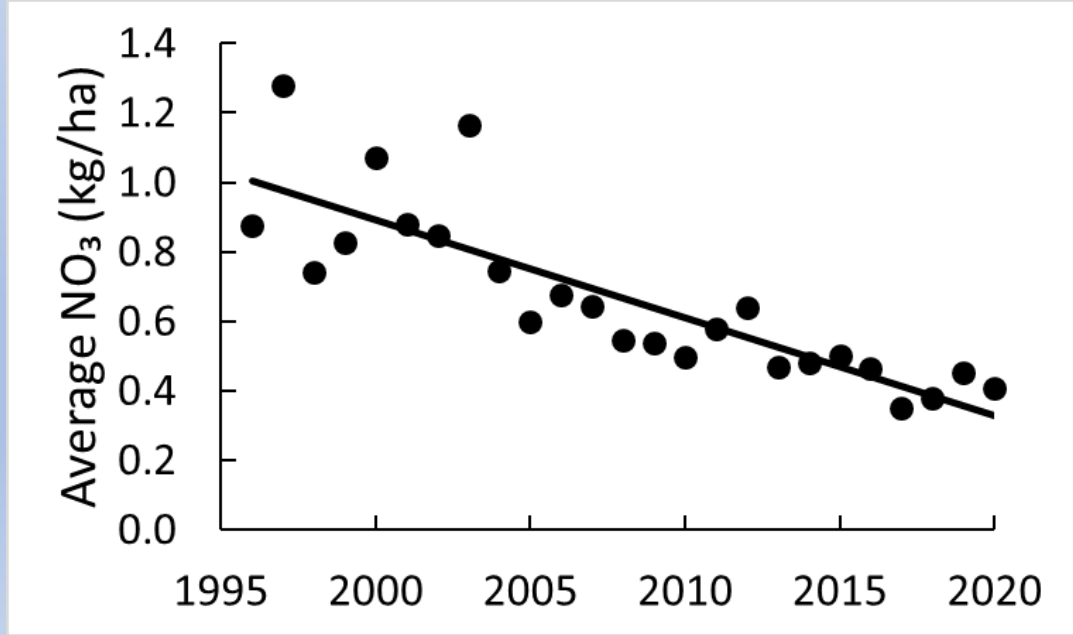
Precipitation quantity & quality

Acid rain recovery

- Declines in sulfur and nitrogen byproducts falling through rainwater

- Reflected in precipitation data
  - MA01: Truro, MA



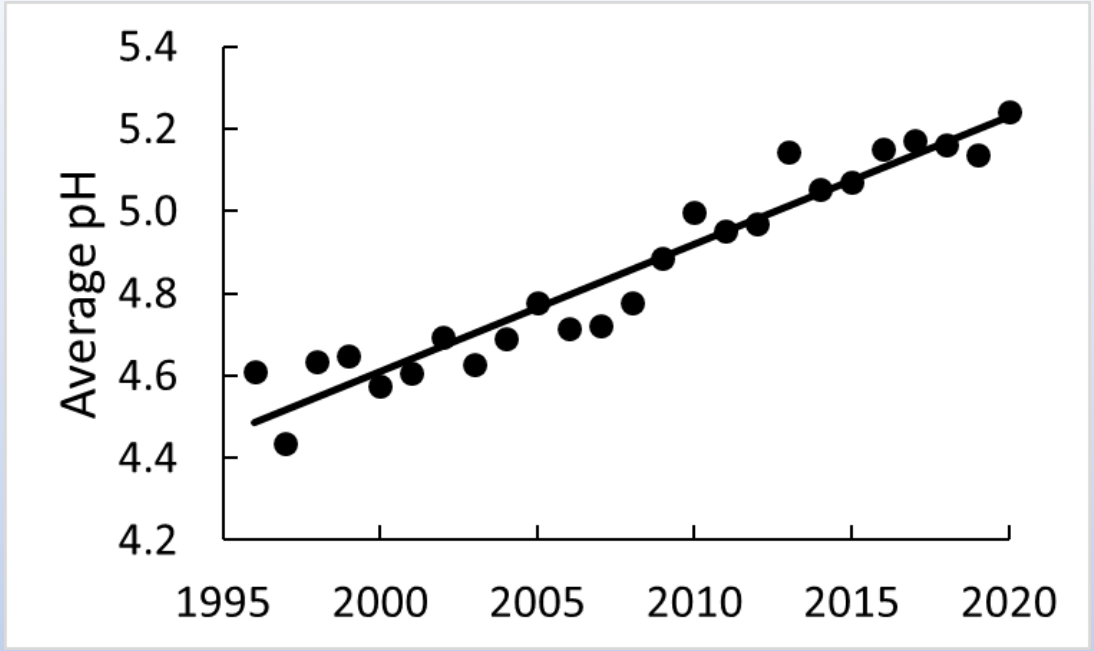


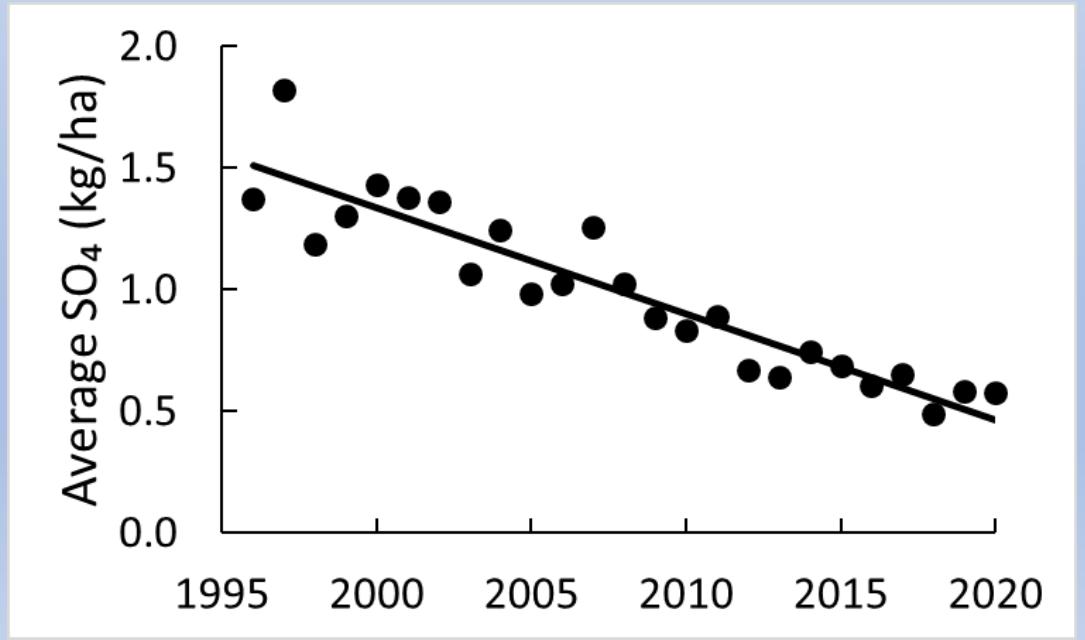
Precipitation quantity & quality

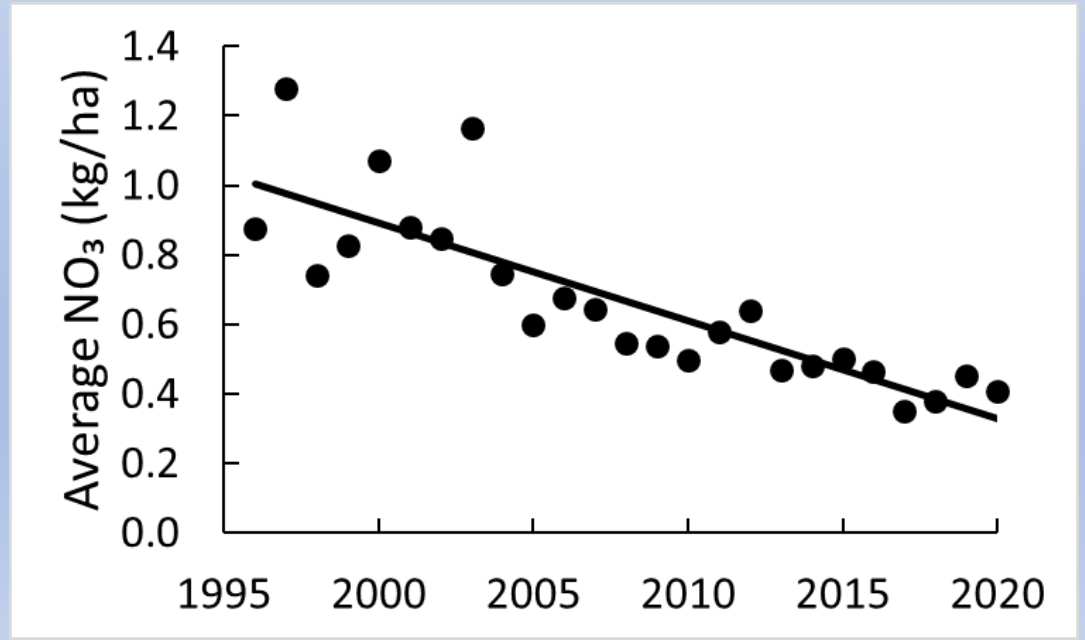
Acid rain recovery

- Acidity of rainwater has decreased one pH unit – approx. 10x less acidic

- Reflected in NADP precipitation data
  - MA01: Truro, MA

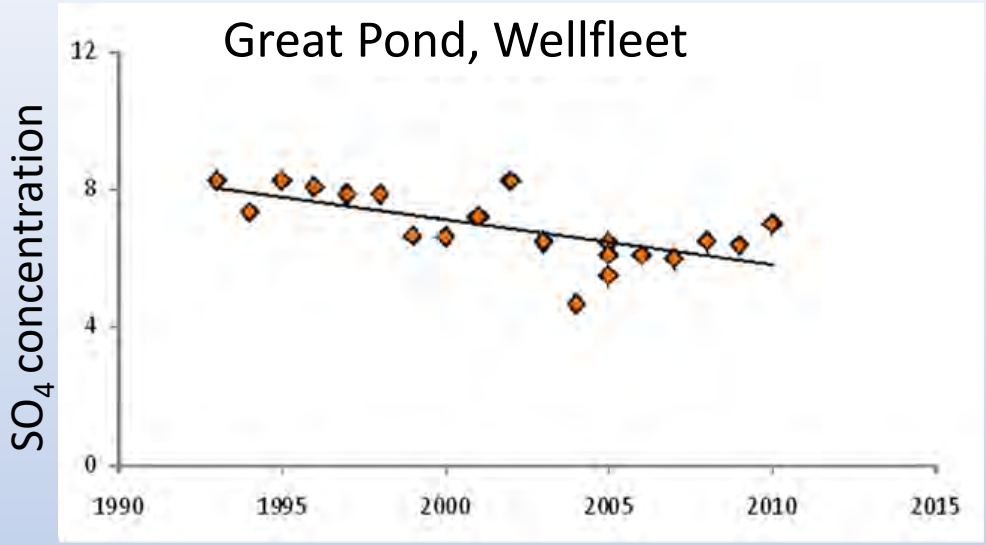


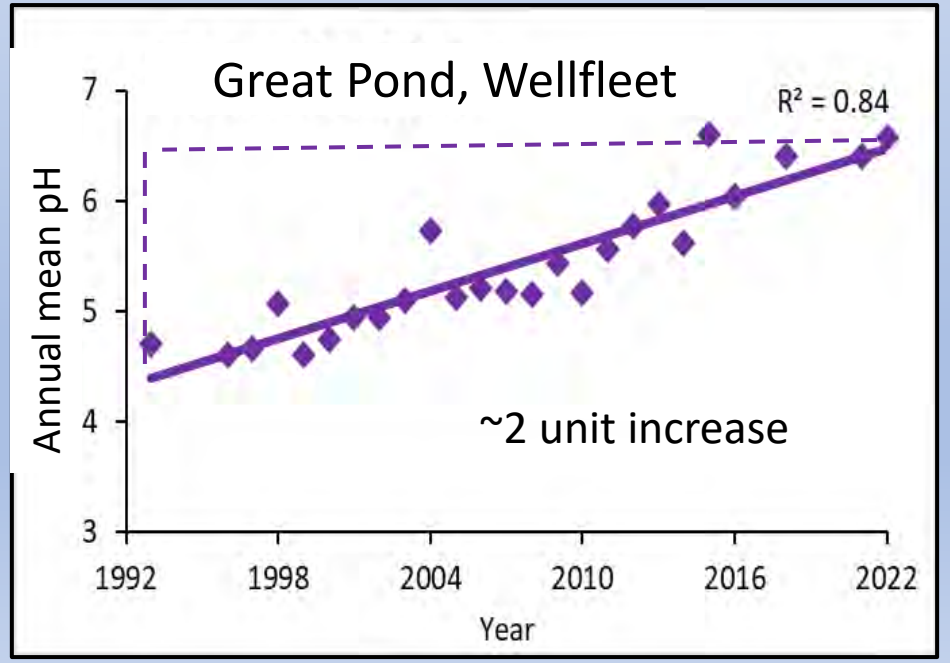




Surface water quality

Effects of acid rain recovery in ponds



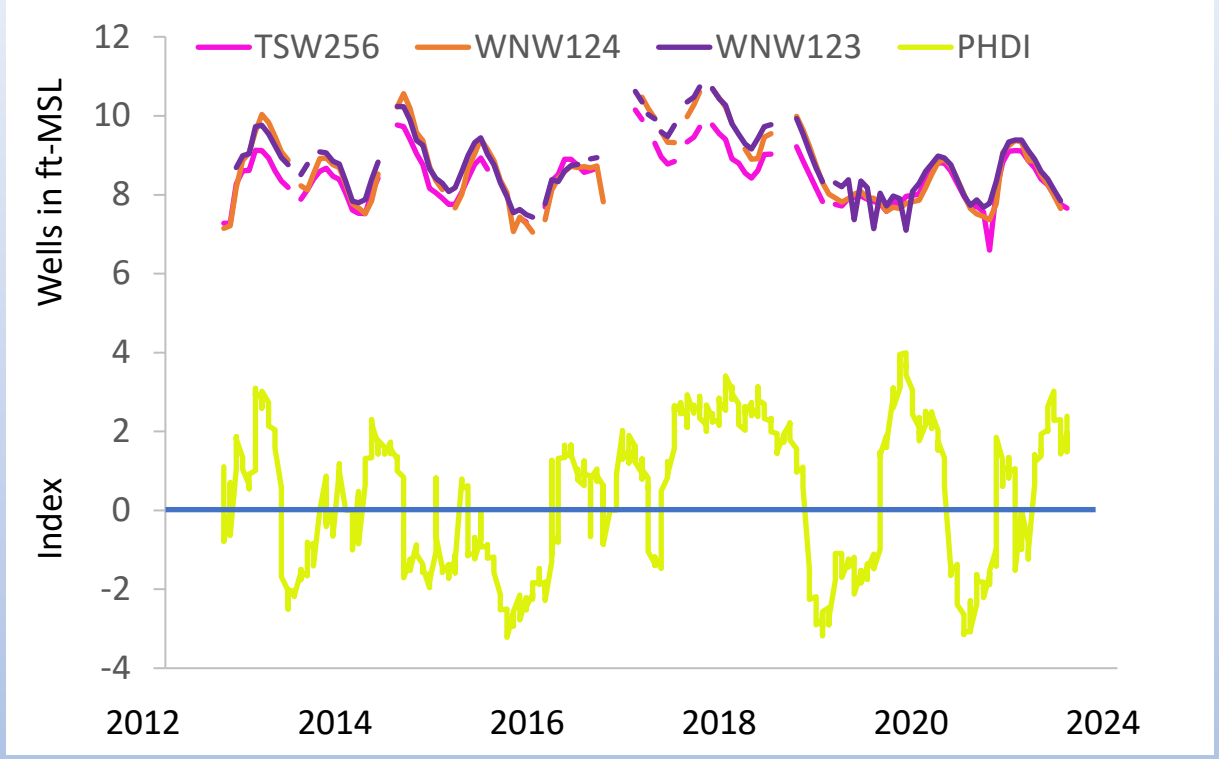


- Sulfate concentrations decreased by nearly half
- Led to increases in pH of about 20x less acidic waters

Groundwater and Surface water quantity

- Groundwater levels look similar in nearby wells
- Fluctuate from season to season, and year to year
- Most closely related to wet and dry climate periods, shown as PHDI

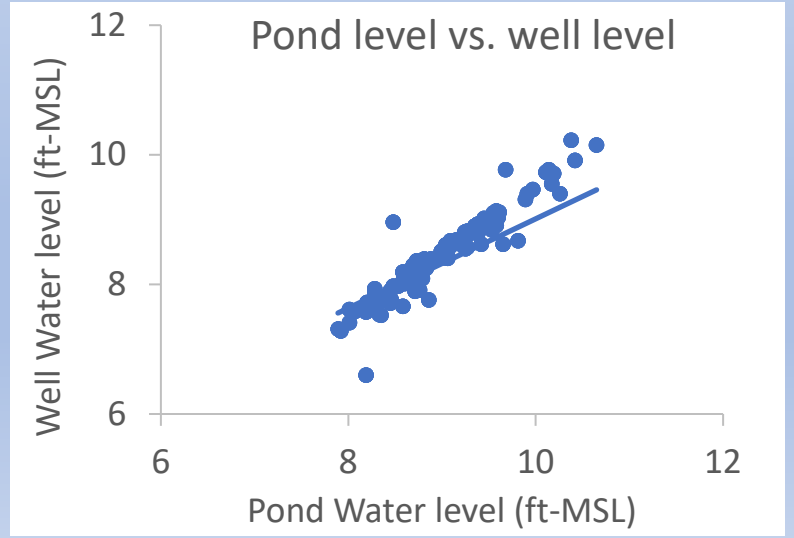
  (Palmer Hydrological Drought Index)

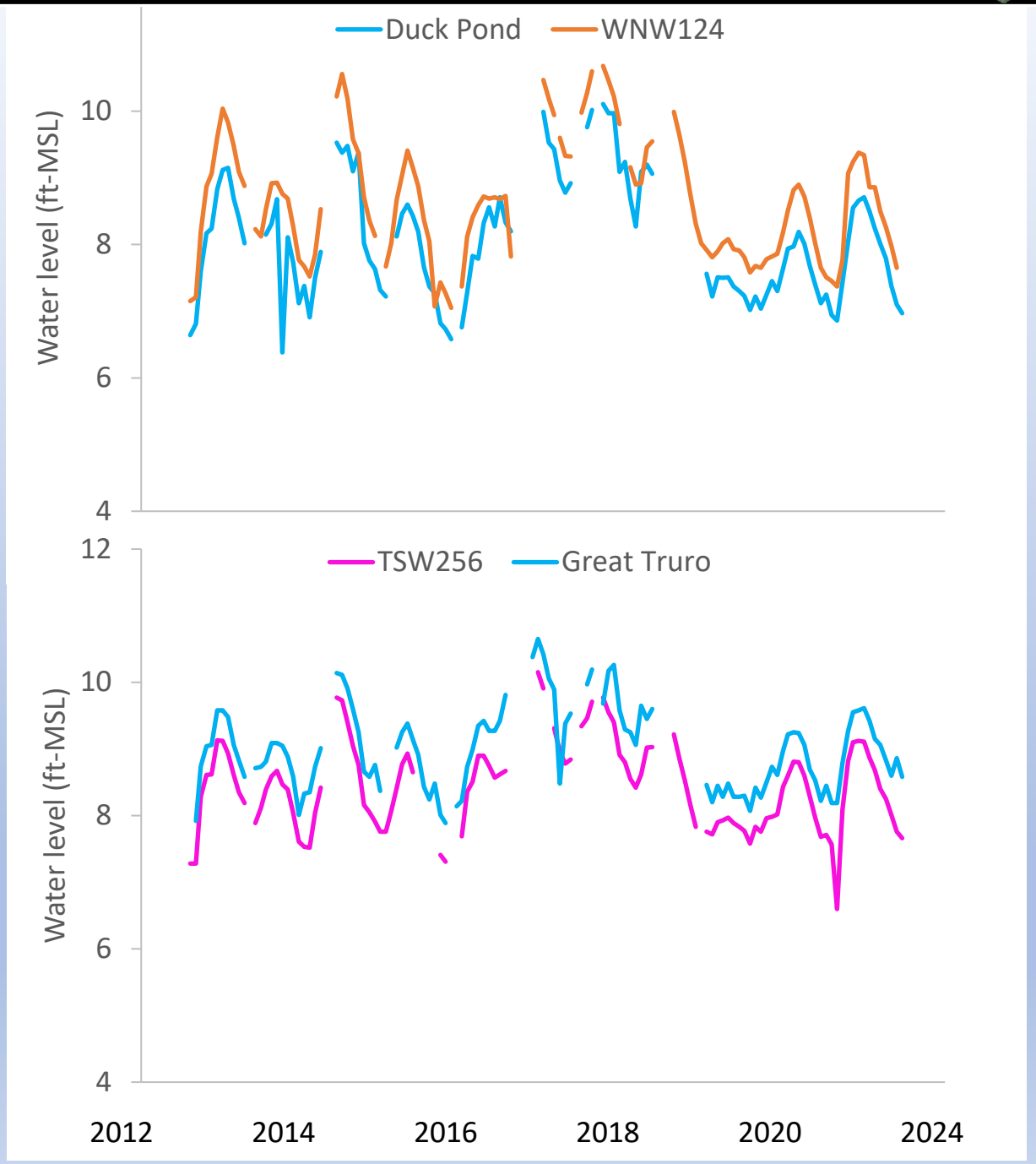


Groundwater and Surface water quantity

- Fluctuate from season to season, and year to year

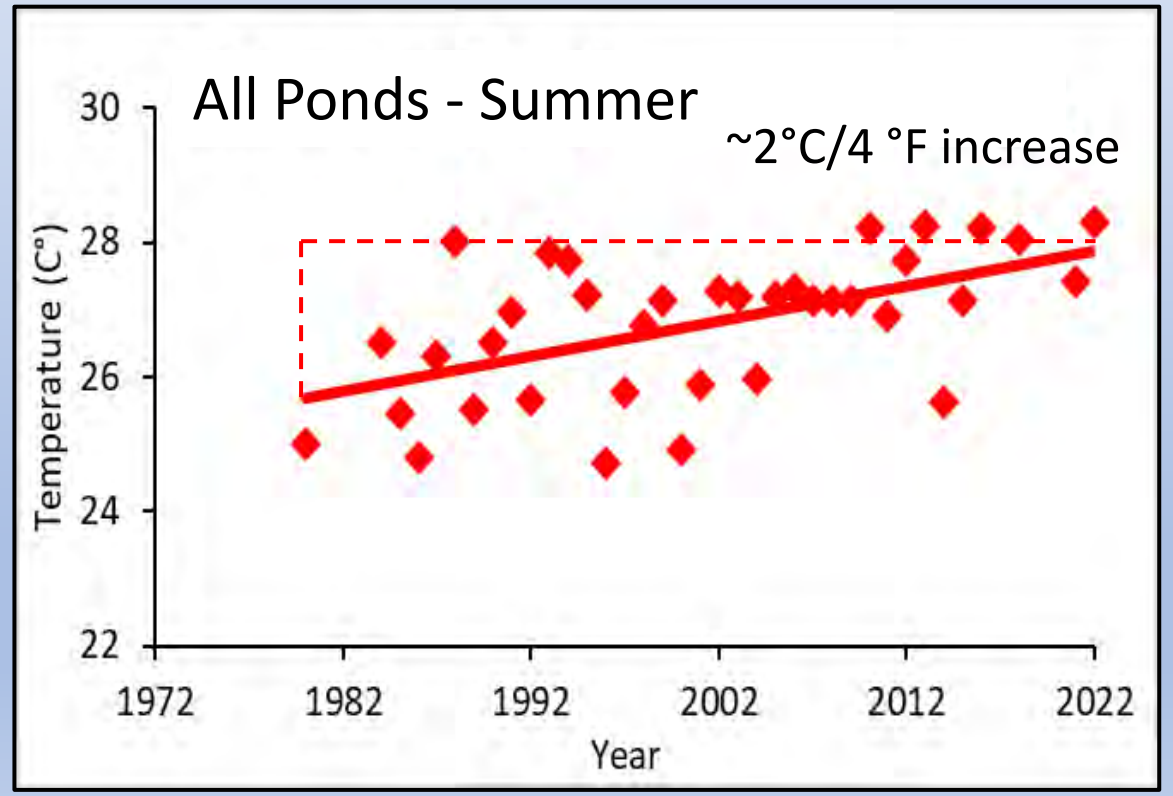
- Groundwater levels are related to pond surface water levels

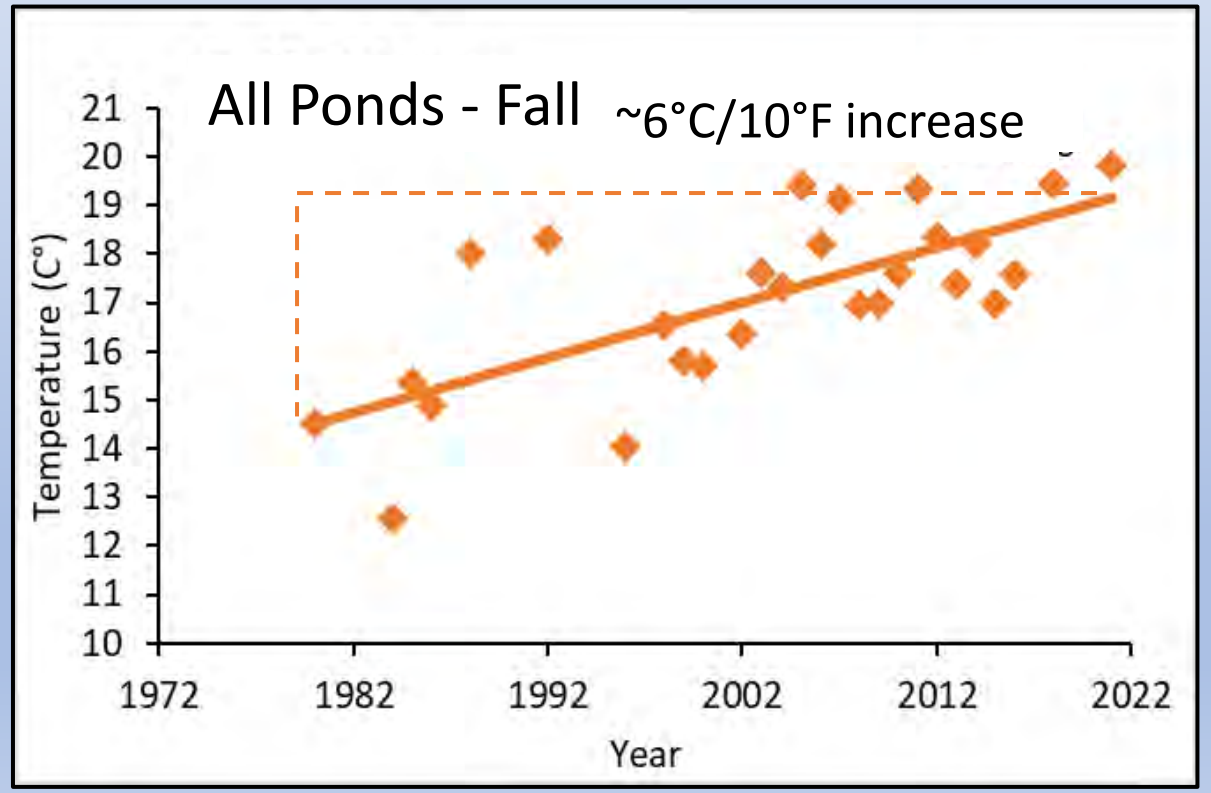




Surface water quality

- Climate warming is affecting pond temperatures
- Pond temperatures are increasing over last several decades
- Summer and fall warming of pond waters





Impacts of Changing Climate on Ponds

Climate-related impacts exacerbate local threats

- High nutrient inputs from septic and fertilizers
- Shoreline development and vegetation removal

Drought

- Low water levels
- Alterations to shoreline and nearshore emergent vegetation
- Increased trampling of vegetation

Impacts of Changing Climate on Ponds

POND SCUM

Cyanobacteria Blooms Rise With Water Temperatures

Swimmers are advised to learn to spot and report ephemeral blooms

BY NORA MARKEY & BENJAMIN SIEGEL · AUG 10, 2022

Year	# Observed Blooms	# Ponds w/ blooms
2019	1	1
2020	1	1
2021	2	2
2022	14	7

As temperatures rise, a 'nightmare' of toxic algae plagues the hidden gems of Cape Cod

By David Abel Globe Staff, Updated July 31, 2020, 10:43 a.m.

Why do we care about cyanobacteria blooms?

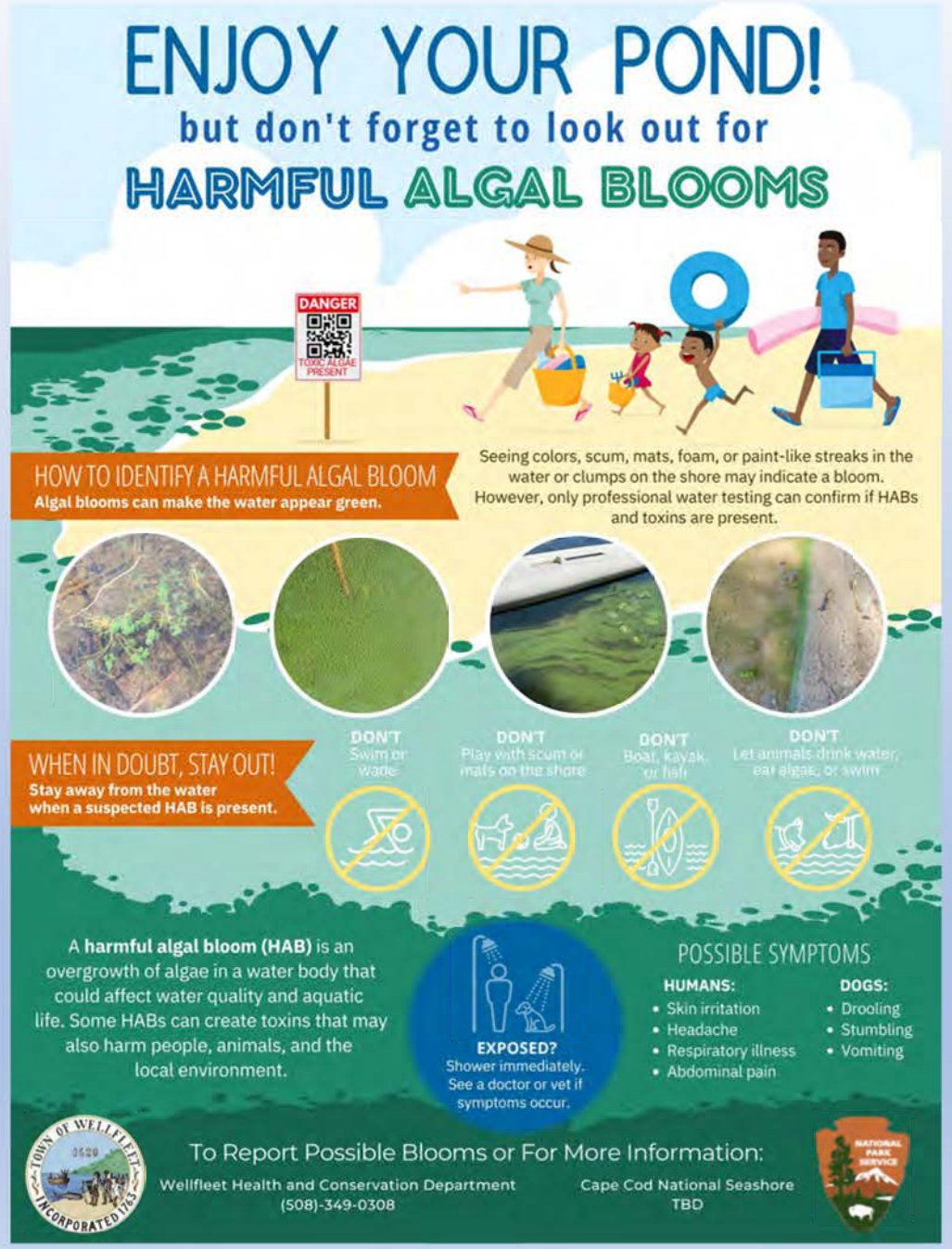
HABs are dangerous to you, your family, and your pets

- People and pets should not swim in waters where an algae bloom is visible

- Accidentally ingesting affected water during recreation may make you and/or your pet very ill or even die

2024 Cyanobacteria Work

- Goal: increase our capacity to observe blooms by encouraging bloom reporting by the public (we cannot be at the ponds enough to monitor these conditions)
- Increase and improve public communications – e.g., signage, public presentations and social media information
- Increase information sharing among partners
- Better application of health advisories to protect both humans and pets
- Work with partners and seeking funding to better understand how blooms form and their toxicity



Cape Cod National Seashore Science

- Scientific research papers from CACO freshwater data

Water Air Soil Pollut (2016) 227:237
DOI 10.1007/s11270-016-2916-x

Changes in Air Temperature and Precipitation Chemistry Linked to Water Temperature and Acidity Trends in Freshwater Lakes of Cape Cod National Seashore (Massachusetts, USA)

Stephen M. Smith · Sophia E. Fox · Krista D. Lee

LAKE AND RESERVOIR MANAGEMENT
2018, VOL. 34, NO. 1, 88–103
https://doi.org/10.1080/10402381.2017.1390017

Secchi depths in lakes of Cape Cod National Seashore from 1996–2016 and relationships with morphometry, water chemistry, and housing densities

Stephen M. Smith, Sophia E. Fox, Krista D. Lee, Kelly Medeiros, and Holly C. Plaisted

National Park Service, Cape Cod National Seashore, Wellfleet, MA

INLAND WATERS, 2018
https://doi.org/10.1080/20442041.2018.1427949

Changes in the thermal structure of freshwater lakes within Cape Cod National Seashore (Massachusetts, USA) from 1996 to 2014

Stephen M. Smith, Sophia E. Fox, Holly K. Plaisted, K. Medeiros, and Krista D. Lee

National Park Service, Cape Cod National Seashore, Wellfleet, MA, USA

Recent groundwater and lake-stage trends in Cape Cod National Seashore: relationships with sea level rise, precipitation, and air temperature

Stephen M. Smith and Kelly C. Medeiros

2019 Journal of Water and Climate Change

Looking Ahead

Why monitoring our freshwater systems is so important:

- Our global and local climates are seeing more extreme shifts in temperature and other climate-related events
- The physical structure, chemistry and biology are changing over short time scales
- Many changes are harmful to human health, as well as ecological integrity, e.g., cyanobacteria blooms
- Allow for a comprehensive view of how Cape Cod's coastal landscape is affected by local and distant threats

Explore Data & Additional Resources and Partnerships

National Atmospheric Deposition Program
Monitoring precipitation chemistry since 1978

nadp.slh.wisc.edu/networks/

Water Resources Division

[Water Resources Division (U.S. National Park Service) (nps.gov)]

APCC Association to Preserve Cape Cod

[Association to Preserve Cape Cod | Preserving Nature for 50 Years (apcc.org)]

National Centers for Environmental Information
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

[Weekly Palmer Drought Indices | Divisional Time Series | National Centers for Environmental Information (NCEI) (noaa.gov)]

[Water Resources | Cape Cod Commission]

CAPE COD COMMISSION

[Estimating High Groundwater Levels | Cape Cod Commission]

CAPE COD COMMISSION

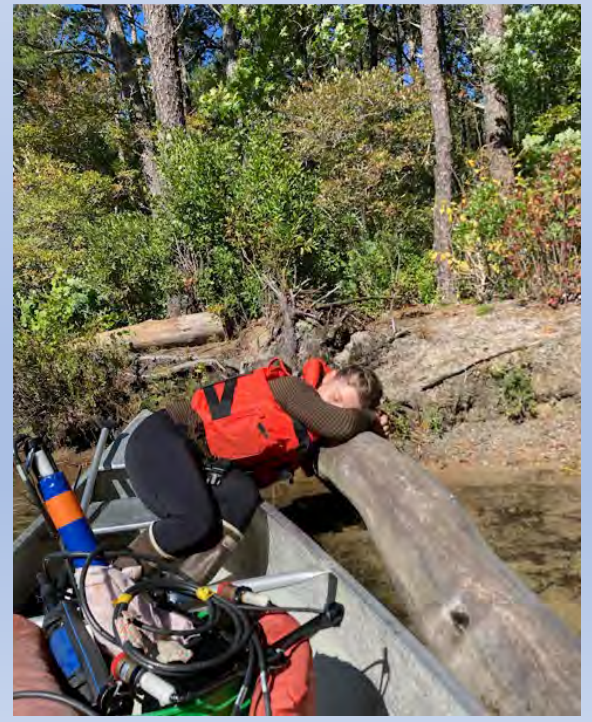
[USGS Groundwater Data for the Nation]

[Dashboard]

Monitoring is hard work...

Thank you!

I acknowledge the many technicians, interns, and volunteers that made this possible!!!



Eastham -Phase I 2015
-Waterline extensions 2022 -2024

Truro (N Union Field) -Waterline 2012

Wellfleet – Pumping began 2010