

Recent Trends in Sunshine, Visibility and Cloud Cover at the Blue Hill Meteorological Observatory

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Mount Washington Observatory
Science in the Mountains Webinar
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Outline

- What is Causing Recent Changes in Sunshine and Visibility at BHO?
- How are Sunshine and Visibility Measured at BHO?
- Role of Trends in Visibility, Air Quality, and Cloud Cover on Sunshine Changes



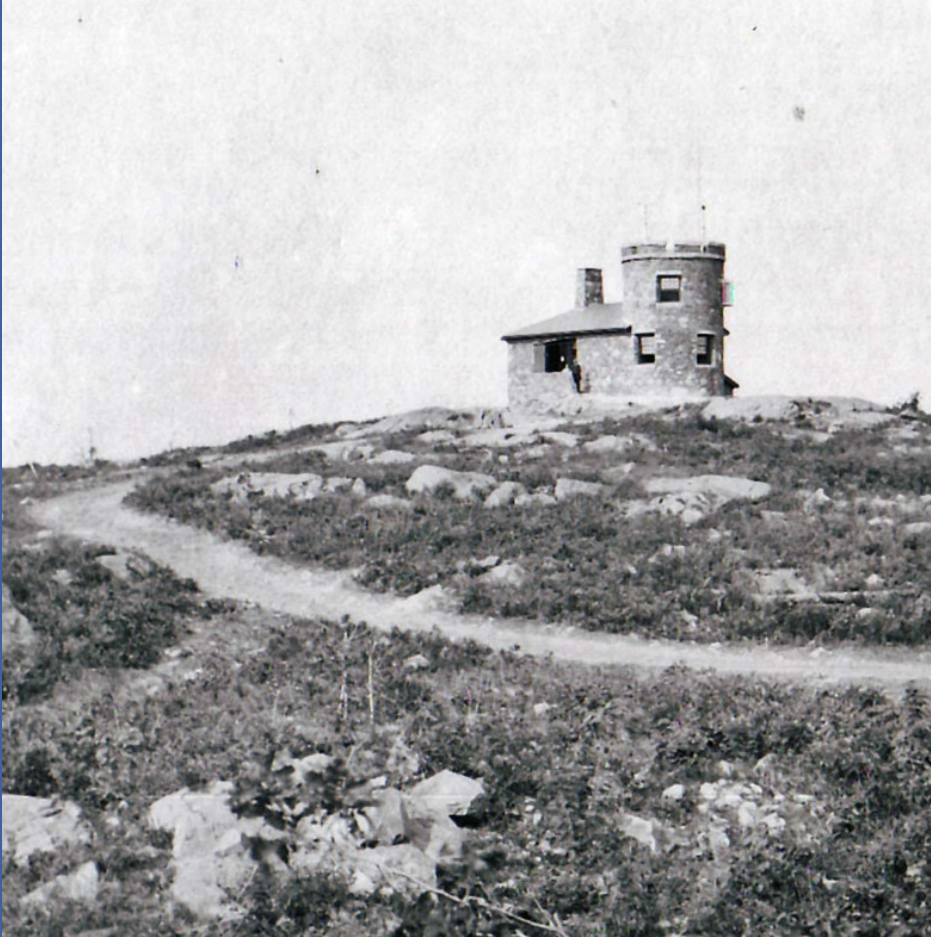
bluehill.org/observatory

BHO Mission:

"Our mission is to foster public understanding of Earth's weather, climate and environmental systems and to continue to produce, maintain, and analyze a meticulous, consistent record of weather and climate observations."

BHO Climate: Observatory

1885



Blue Hill Observatory,
Great Blue Hill, Milton, MA

2011



BHO Climate: Observations

- Parameters

Temperature

Relative Humidity

Precipitation

Snowfall

Snow Depth

Wind Speed / Direction

Peak Wind Gust

Station Pressure

Sunshine Duration

Cloud Cover

Cloud Type

Weather Type

Pond Freeze/Thaw Date

Prevailing Visibility

Ozone Amount, etc.

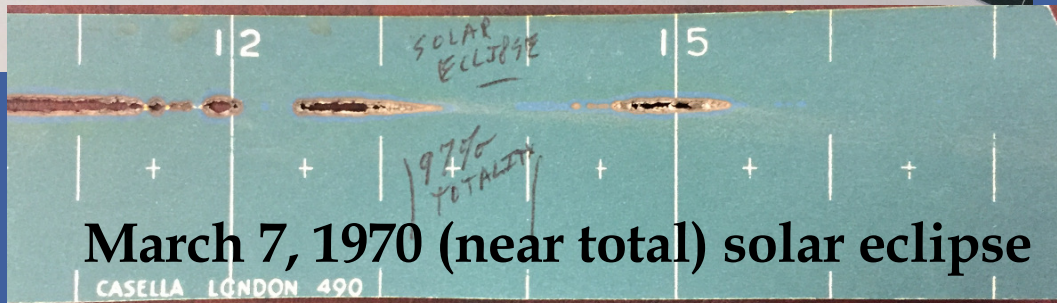
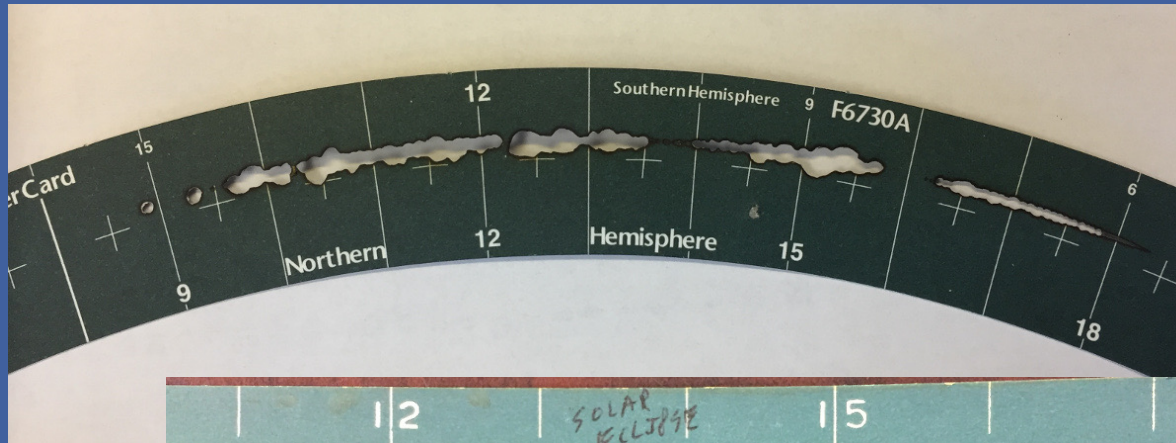


Outdoor instrument enclosure at BHO

BHO Climate: Sunshine Duration

Method: Campbell-Stokes Sunshine Recorders (1885, 1898, 1993)

- Records duration of bright sunshine from direct sun scorching card at focal length below glass sphere
- Percent of possible minutes derived from raw data
- Affected by clouds, air pollution, visibility



March 7, 1970 (near total) solar eclipse



BHO Climate: Visibility

Method: Visual estimate of prevailing visibility and mountains visible

- Prevailing Visibility: Highest distance seen over at least half of the horizon
- Recorded during three manual observations at 7 AM, 10 AM, 1 PM EST
- Estimated up to 90 miles depending on the clarity of Grand Monadnock
- Mountain visible also reported (1-3) with clarity indicator (0-3); e.g. 2@1.5
- Three natural markers used to report mountain visible:
 - Mtn #1: Nobscot Hill (Framingham, MA, 20 miles WNW)
 - Mtn #2: Wachusett Mountain (Princeton, MA, 44 miles WNW)
 - Mtn #3: Grand Monadnock (Jaffrey, NH, 68 miles, NW)
- Numerous additional markers used as secondary visibility indicators
 - Houghton's Pond (1 mile, ESE)
 - Boston Harbor (Quincy, MA, 7 miles, NE)
 - State House (Boston, MA, 10 miles, N)
 - Boston Light (Little Brewster Island, 14 miles, ENE)
 - Copicut Hill (Fall River, MA, 34 miles, S)
 - North and South Pack Monadnock (Peterboro, NH, 60 miles, NW)

BHO Climate: Visibility

Images: High Visibility



Boston: 10 miles N-NNE



Grand Monadnock, NH: 68 miles NW



Wachusett Mountain: 44 miles WNW

BHO Climate: Visibility

Images: Reduced Visibility due to Aerosols/Fog/Precipitation



Aerosol Haze over Boston



Heavy Rain Shower



Undercast/Fog

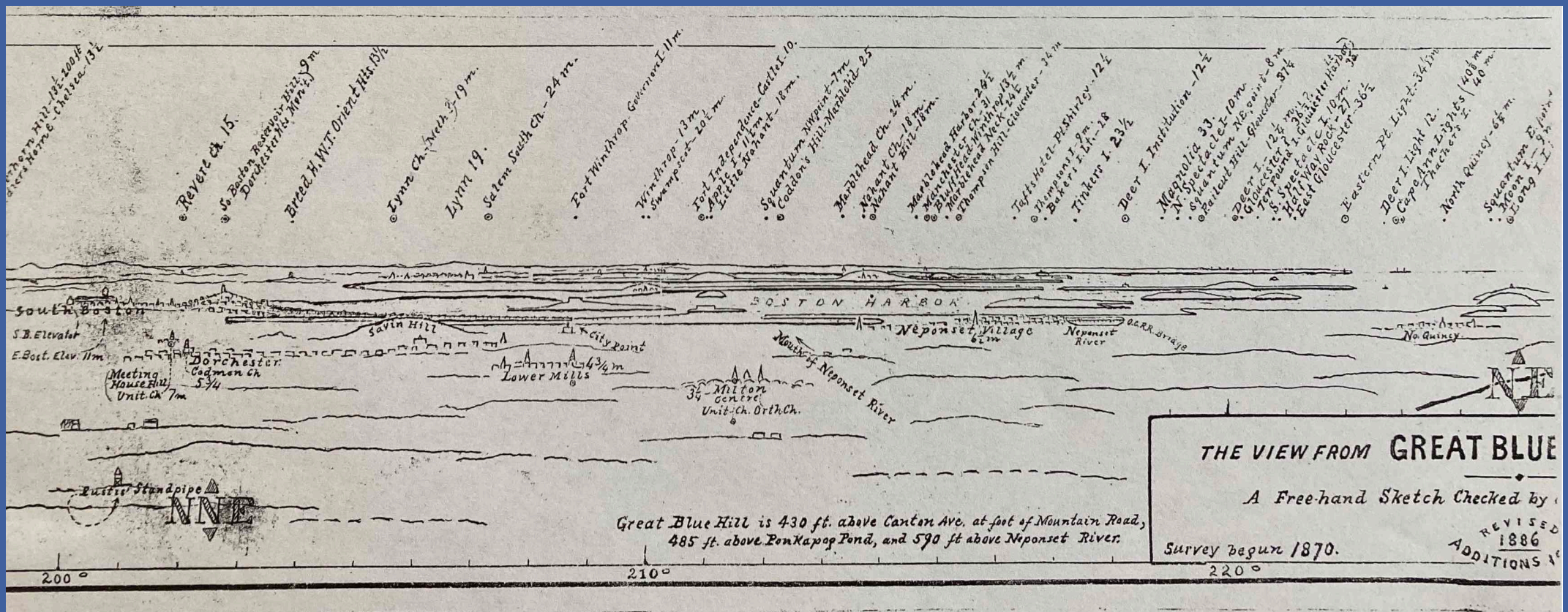
Historic, Hand-Drawn, Distance Charts:

-
- Hills:**
- Hillier Mt. Newton 700-85 ft.
 - Temple Hill 96 ft.
 - Nashua Mt. 2100-574 ft.
 - Newton Lower Falls 104 ft.
 - Newton Upper Falls 104 ft.
 - N. Rock Monks Rock 2260-60
 - Newton Upper Falls School - 9m.
 - Cath. Indian School St. Nicholas
 - Middlebury Orth. Ch. - 114 ft.
 - Sydney S. Peak - 59 m.
 - Sydney Mt. No Peak 60.
 - Sydney Pinnacle - 60 m.
 - Piscataway Mt. 7 Sydney.
 - Lincoln Unit. Ch. - 174 m.
 - Lincoln Unit. Ch. - 174 m.
 - Westford Unit. Ch. - 30 m.
 - Newton Highlands Cong. Ch. - 9 m.
 - Little Prospect - 634 ft. - 132.
 - Prospect Hill - William - 14 m.
 - Warren Unit. Ch.
 - William Rept. Ch. - 12 m.
 - Joe English Hill - Newton
 - William Unit. Ch. - 13 m.
 - Newton Mass. Mt. - 8 m.
 - Kelms Hill - Cambridge - 28 ft.
 - Newton Center Ch. - 9 ft.
 - N. W. Mount - 59 m.
 - The Jones Mt. - 123 ft.
 - Goff's Hill - 50 ft.
- Town Features:**
- East Dedham
 - Bapt. Ch.
 - MYNH Car Shops
 - spragues Pond - 1 m.
 - Readville Trotting Park
 - Chemical Works
 - Bridges
 - Readville
 - Depot 2 m.
 - Readville School
- Rivers & Waterways:**
- Charles River
 - Neponset River
- Scale & Orientation:**
- 1 1/2 miles
 - 140°
 - 150°
 - N.W.
 - N.N.W.

BHO Climate: Visibility

Historic, Hand-Drawn, Distance Charts:

- Survey began 1870, revised in 1886, 1903



BHO Climate: Air Quality

Method: EPA Ozone Concentration and PM 2.5 Measuring Sensors

- Ozone recorded as daily maximum 8-hour average ozone amount
- Ozone Concentration
 - Typical range: 0.02 – 0.08 ppm
- Converted to Air Quality Index (AQI)
 - 0 – 50 (Good)
 - 51 – 100 (Moderate)
 - 101 – 200 (Unhealthy)
 - 201 – 300+ (Hazardous)
- PM 2.5 (Particulate Matter, 2.5 μm)
 - Also called “Aerosols”
 - Typical range: 0 – 50 $\mu\text{g}/\text{m}^3$



EPA Ozone
Equipment Shack

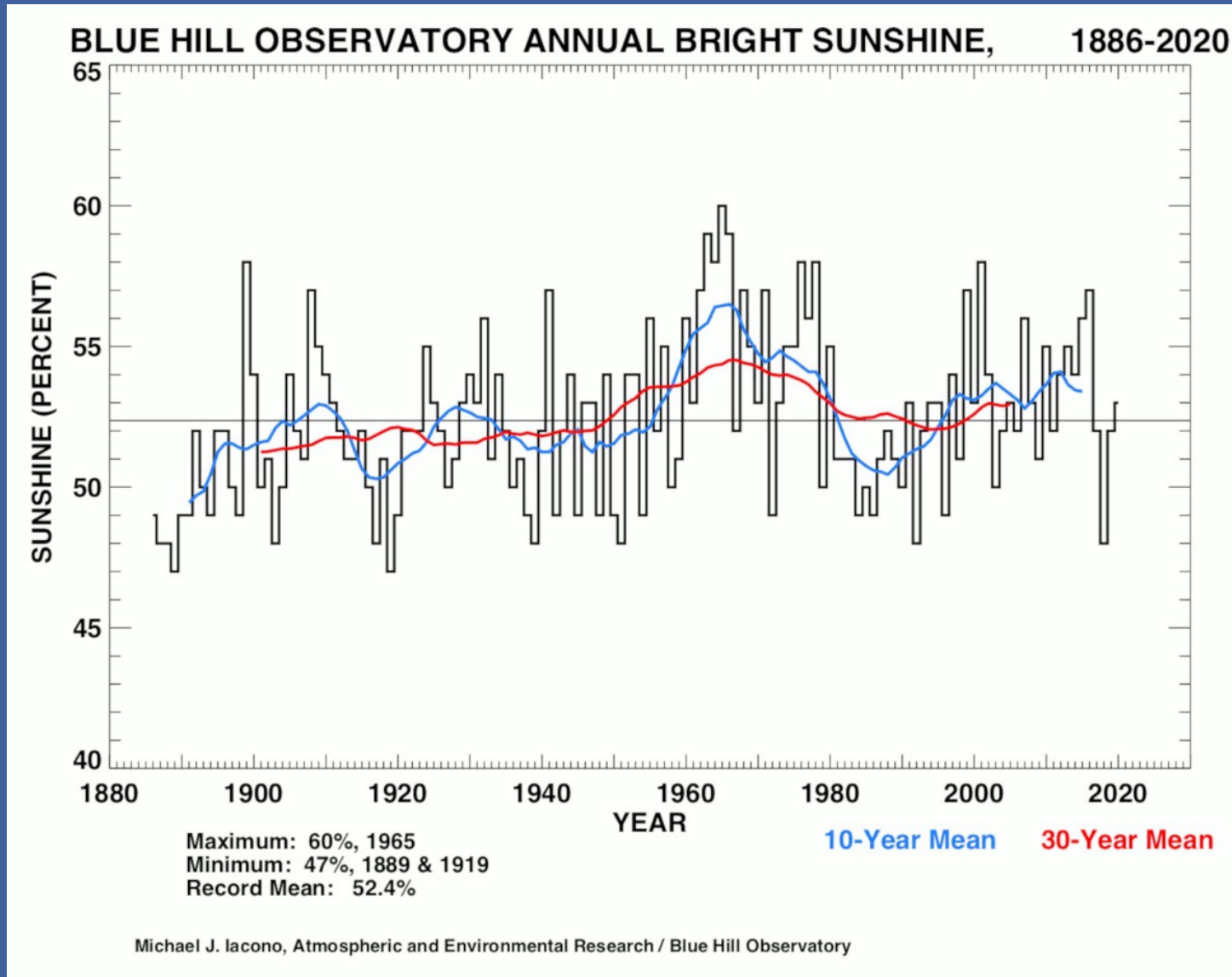
BHO Climate: Cloud Cover

Method: Visual estimate of fraction of sky covered by clouds

- Manually observed three times per day at 7 AM, 10 AM, 1 PM EST
- Currently recorded as eighths of the sky
 - 0/8 to 8/8 = Cloud Fraction
 - 0/8 = No Clouds
 - 8/8 = Fully Overcast,
no blue sky visible
- Represents cumulative sky cover due to all cloud layers viewed from surface
- "Thin" cloud (blue sky visible) is distinguished from "dense" clouds (no blue sky visible)

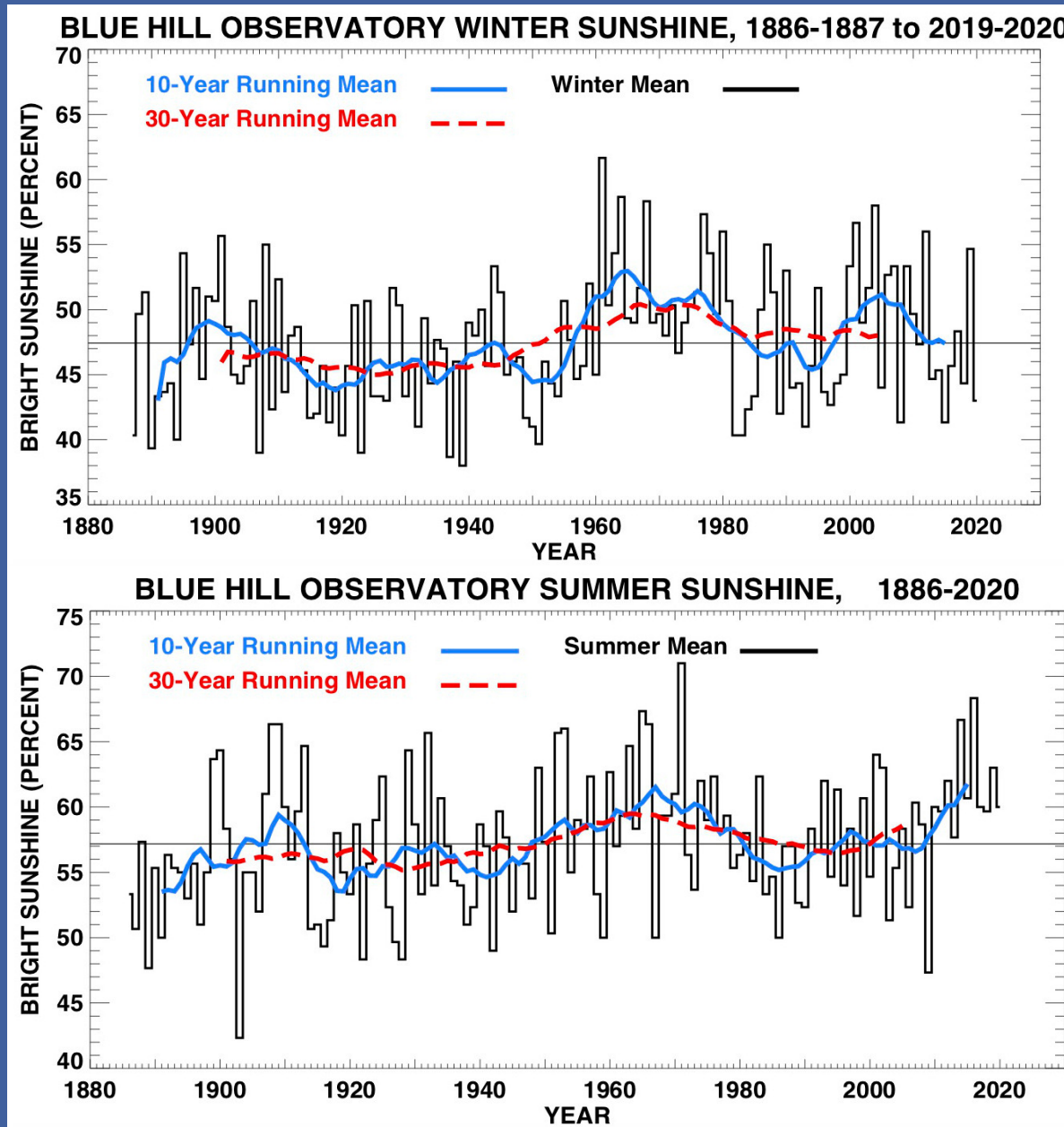


BHO Climate: Annual Mean Sunshine Duration



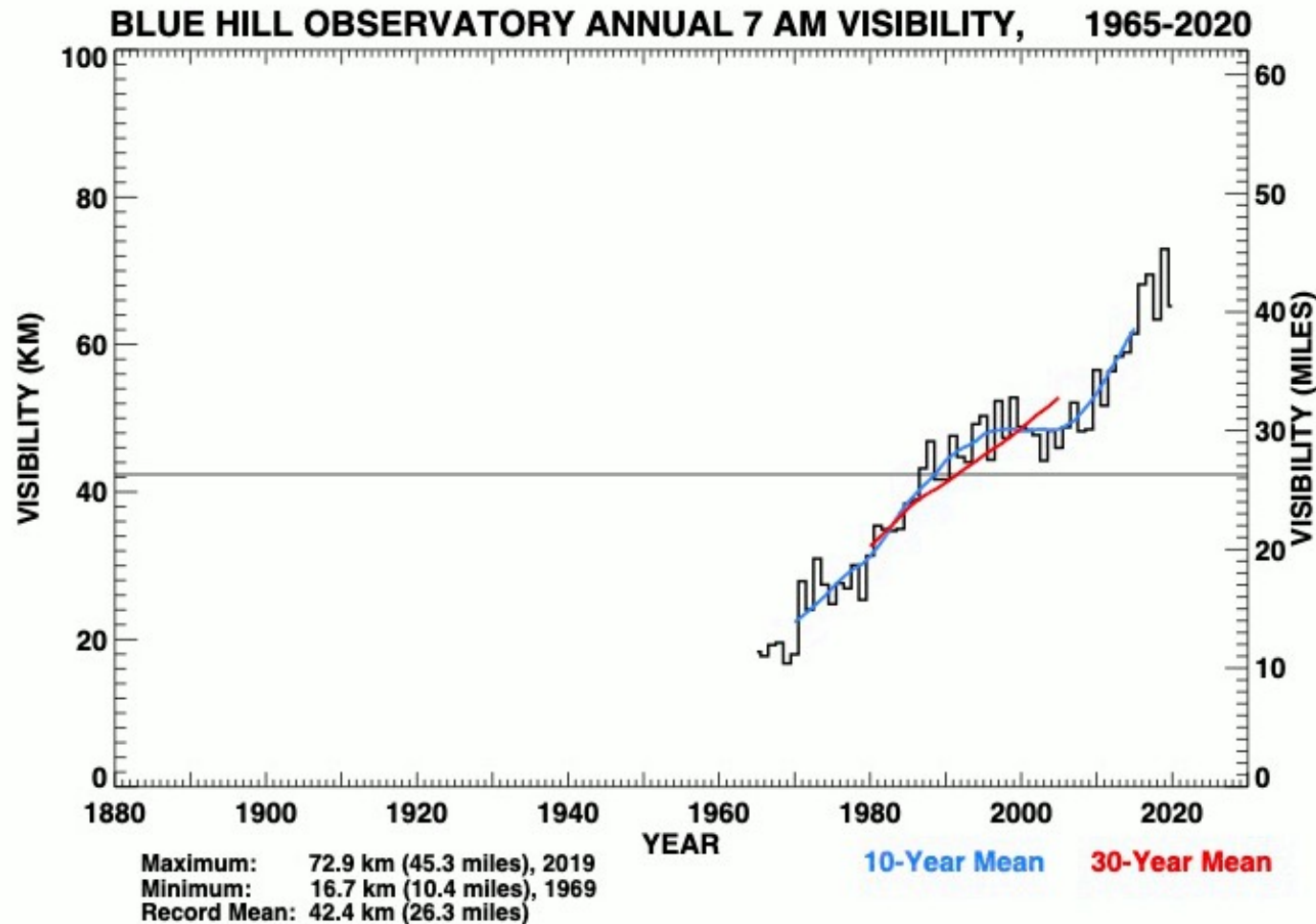
- No significant overall trend in bright sunshine
- Decadal variations since 1950's reflect changes in clouds and air quality (air pollution)
- Sunshine has increased since 1990's due to less air pollution
- Sunniest years (1963-1966) were also very dry

BHO Climate: Seasonal Mean Sunshine Duration



- Highest values in 1960's in winter and summer
- Reduced sunshine during 1980's into 1990's
- Response since 1990 differs by season likely due to clouds

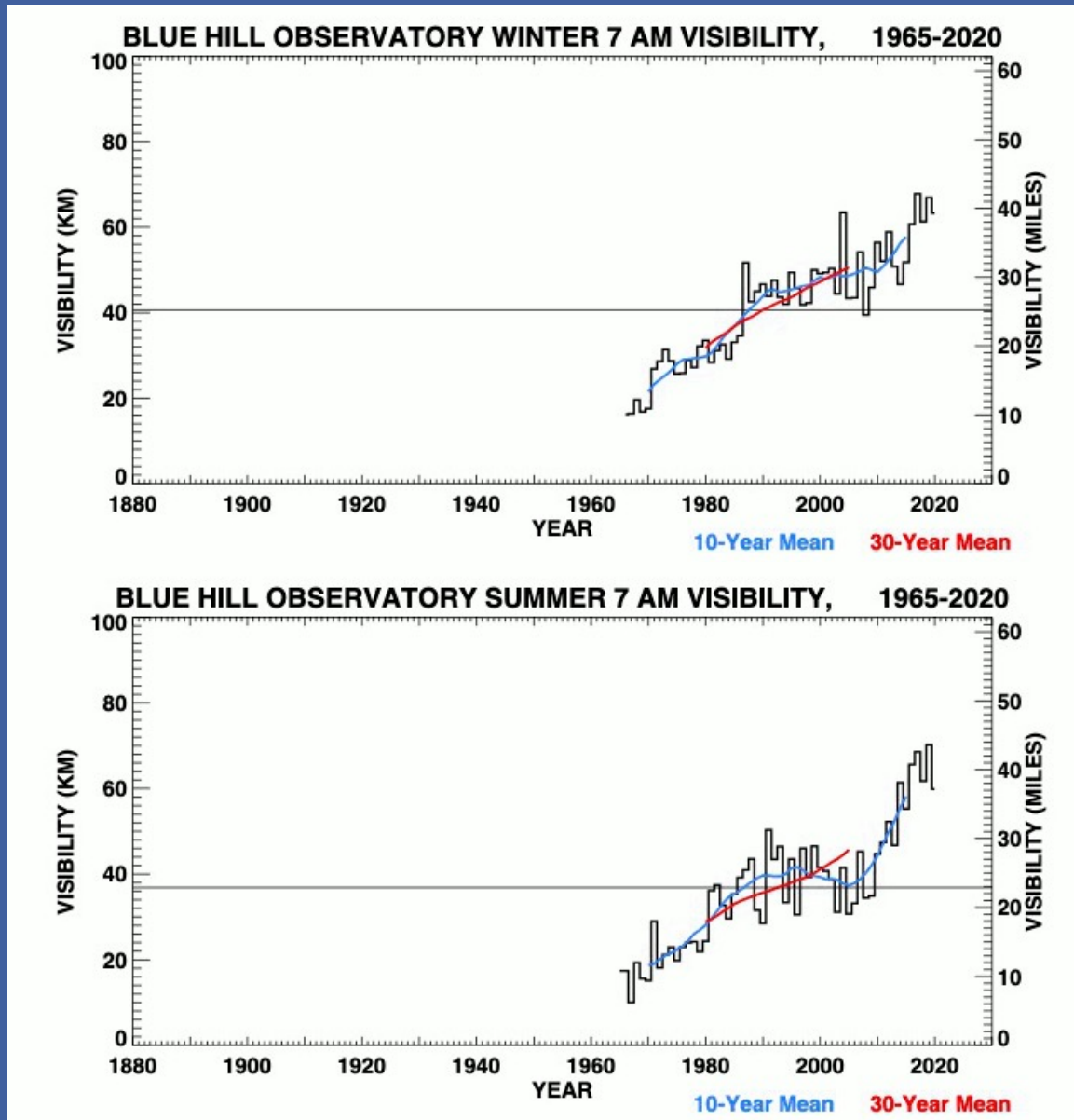
BHO Climate: Annual Mean 7 AM Prevailing Visibility



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- Visibility observed at 7 AM local time
- Significant increase since 1960's likely due to improved air quality
- Brief interruption around 2000
- Higher visibility → more sunshine

BHO Climate: Seasonal Mean 7 AM Prevailing Visibility



- Winter & Summer visibility observed at 7 AM local time
- Significant increase since 1960's likely due to improved air quality
- Larger disruption in trend around 2000 in summer than in winter

BHO Climate: Air Quality / Ozone Amount

Daily Max 8-hour Ozone Concentrations from 01/01/00 to 12/31/21

Parameter: Ozone (Applicable standard is .070 ppm)

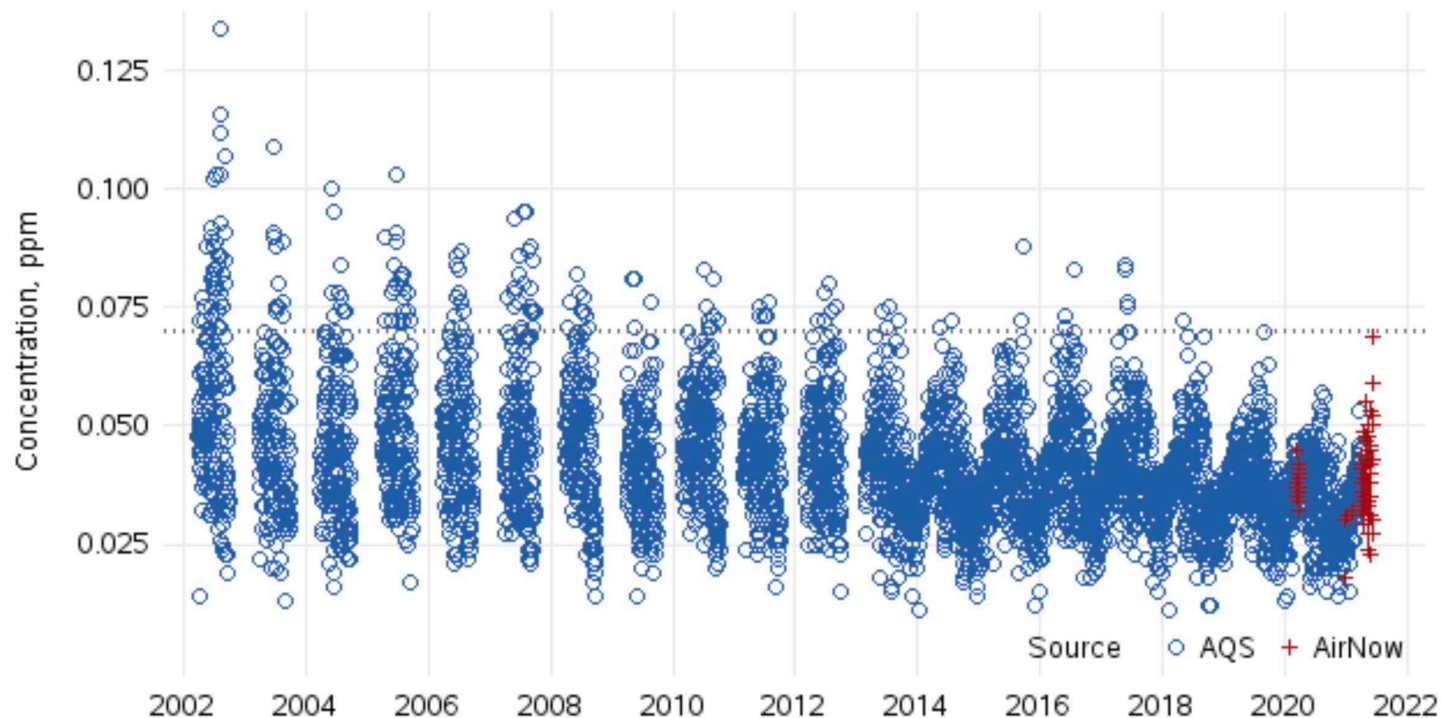
CBSA: Boston-Cambridge-Newton, MA-NH

County: Norfolk

State: Massachusetts

AQS Site ID: 250213003, poc 1

Local Site Name: BLUE HILL OBSERVATORY



Source: U.S. EPA AirData <<https://www.epa.gov/air-data>>

- Maximum 8-hour average ozone concentration
- Steady decline with lower annual range
- Lowest average during 2020 due to less traffic and industrial activity during pandemic

BHO Climate: Air Quality / Aerosols

Daily Mean PM2.5 Concentrations from 01/01/00 to 12/31/21

Parameter: PM2.5 – Local Conditions (Applicable standard is 35 ug/m3)

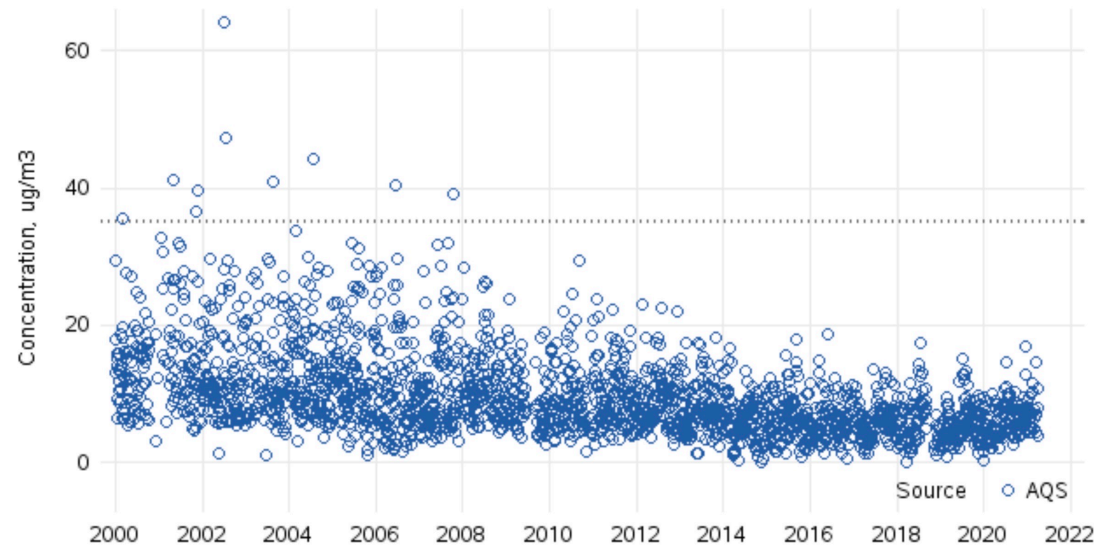
CBSA: Boston–Cambridge–Newton, MA–NH

County: Suffolk

State: Massachusetts

AQS Site ID: 250250002, poc 1

Local Site Name: BOSTON KENMORE SQ



Source: U.S. EPA AirData <<https://www.epa.gov/air-data>>

Daily Mean P

Parameter: Acceptable PM2.5 AQI & !

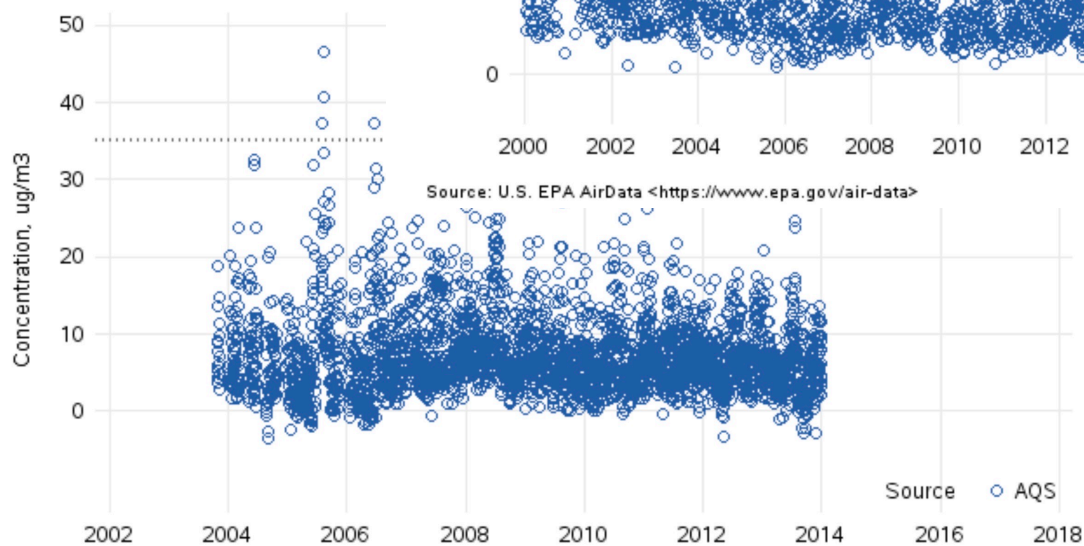
CBSA: Boston–Cambridge–Newton, M.

County: Norfolk

State: Massachusetts

AQS Site ID: 250213003, poc 3

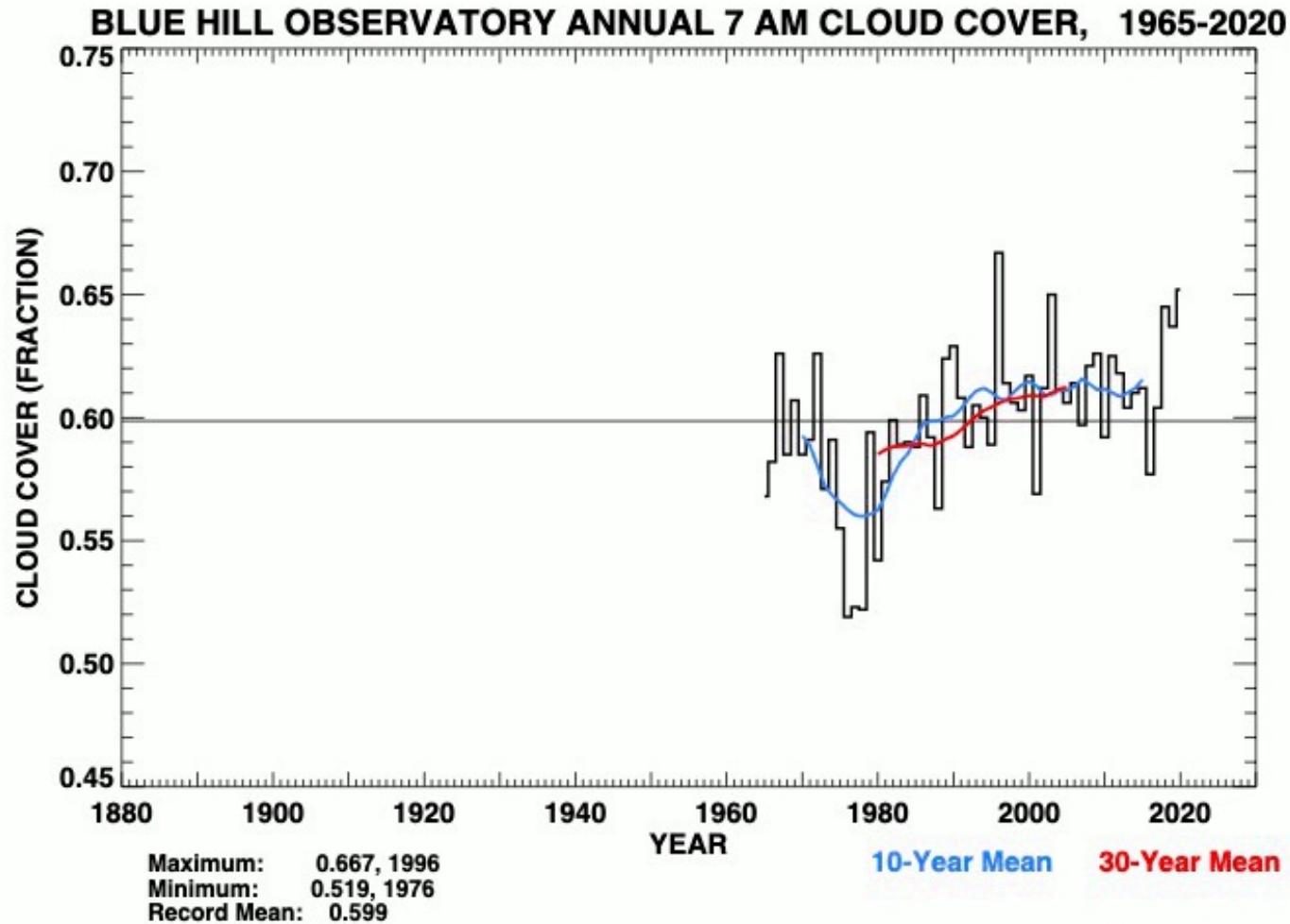
Local Site Name: BLUE HILL OBSERVA



Source: U.S. EPA AirData <<https://www.epa.gov/air-data>>

- EPA PM2.5 aerosol in eastern MA
- Decreasing with smaller annual cycle in Boston (top right)
- Slight decrease at BHO (lower left); record ended in 2014
- Reduced aerosol → more sunshine

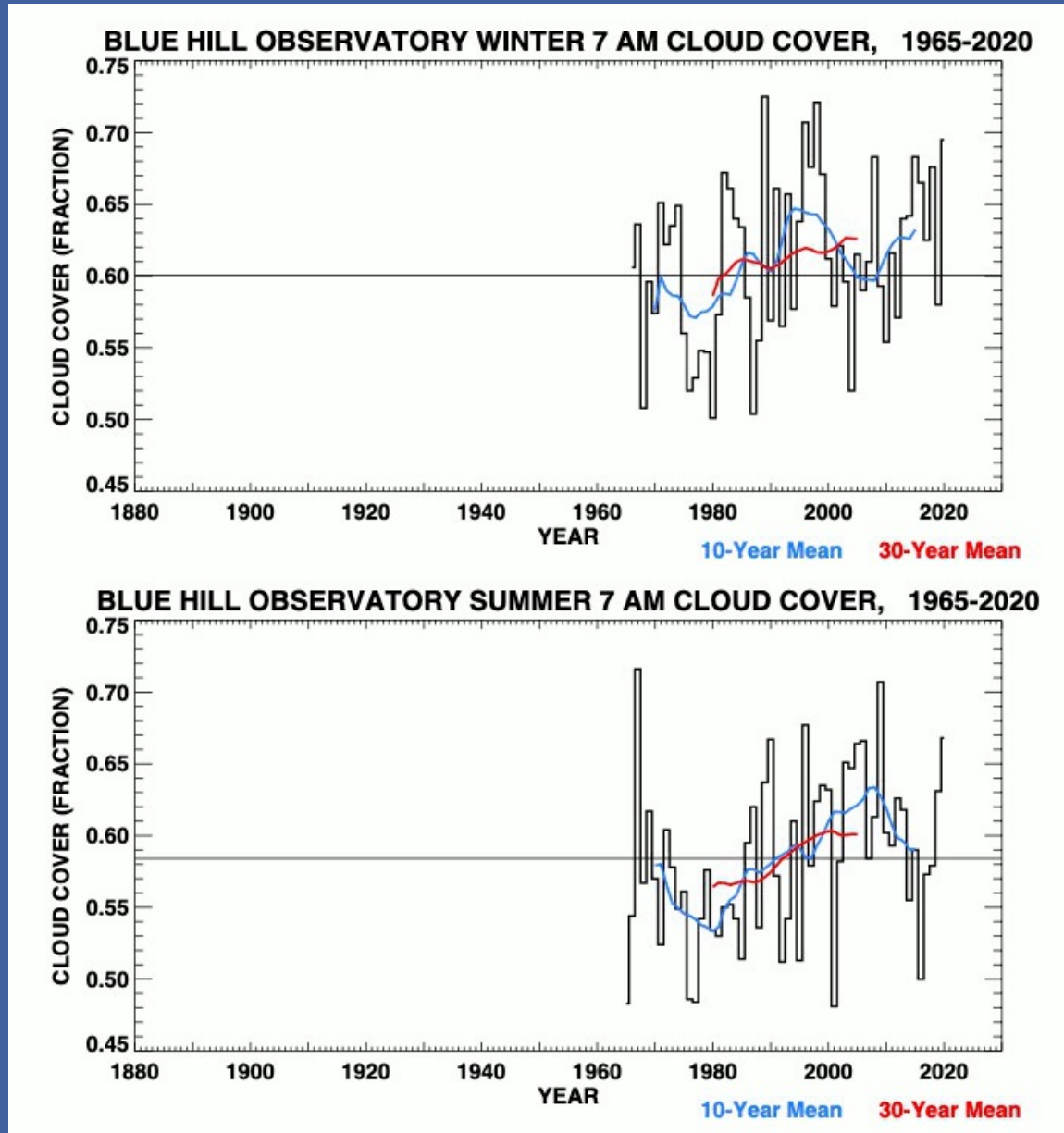
BHO Climate: Annual Mean 7 AM Cloud Cover



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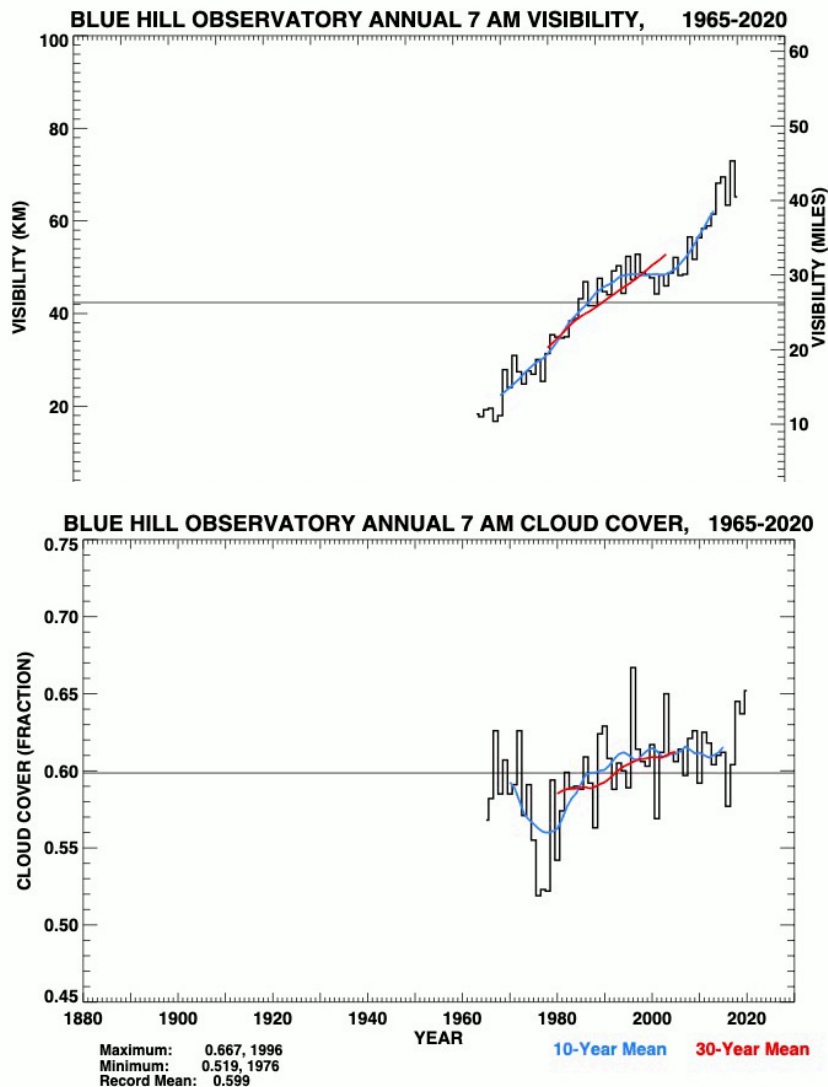
- Cloud cover observed at 7 AM local time
- Small increase in cloud cover since 1970's
- Cause of cloud changes not yet known
- Fewer clouds → more sunshine

BHO Climate: Seasonal Mean 7 AM Cloud Cover

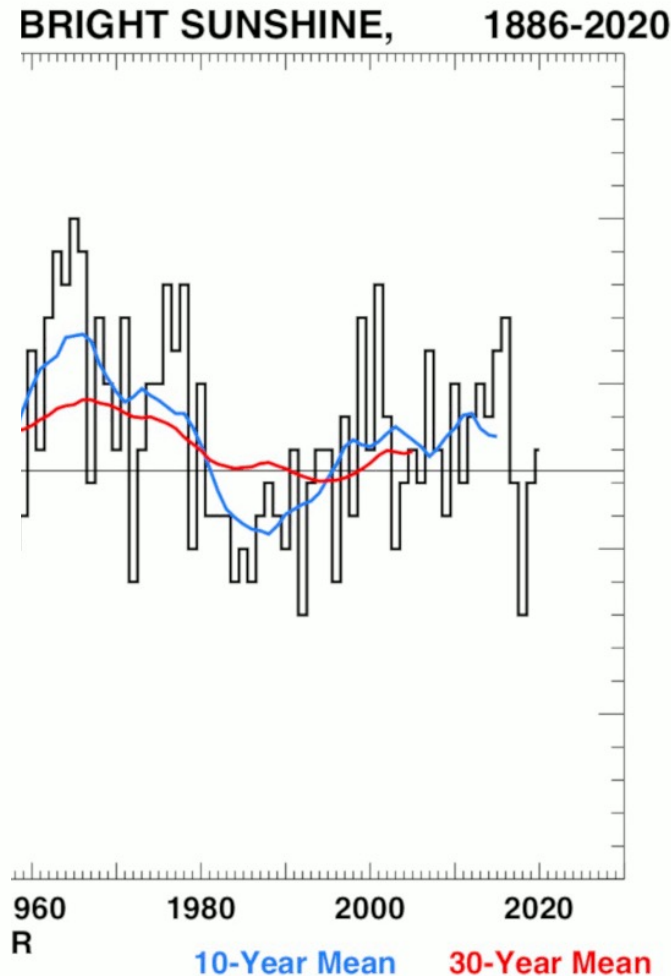


- Winter & Summer cloud cover at 7 AM local time
- Cloud changes vary by season
- Small increases since 1960's

BHO Climate: Sunshine, Visibility & Cloud Cover



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Blue Hill Observatory

- Annual sunshine follows cloud cover more closely in 1960's to 1980's
- Annual sunshine responding to improved visibility since 1990's

BHO Climate: Summary

- Investigating causes of recent decadal variations in sunshine duration at BHO
- Looking at contributions from air quality/aerosol, visibility, cloud cover
- Significant increases in prevailing visibility since mid-1960's implies more sunshine
- Improved in air quality and reduced aerosols since 2000 implies more sunshine
- Strong cloud cover impacts on sunshine in 1960's to 1970's; smaller cloud influence since 2000
- Study remains in progress; data entry continuing for visibility and cloud cover for earlier decades



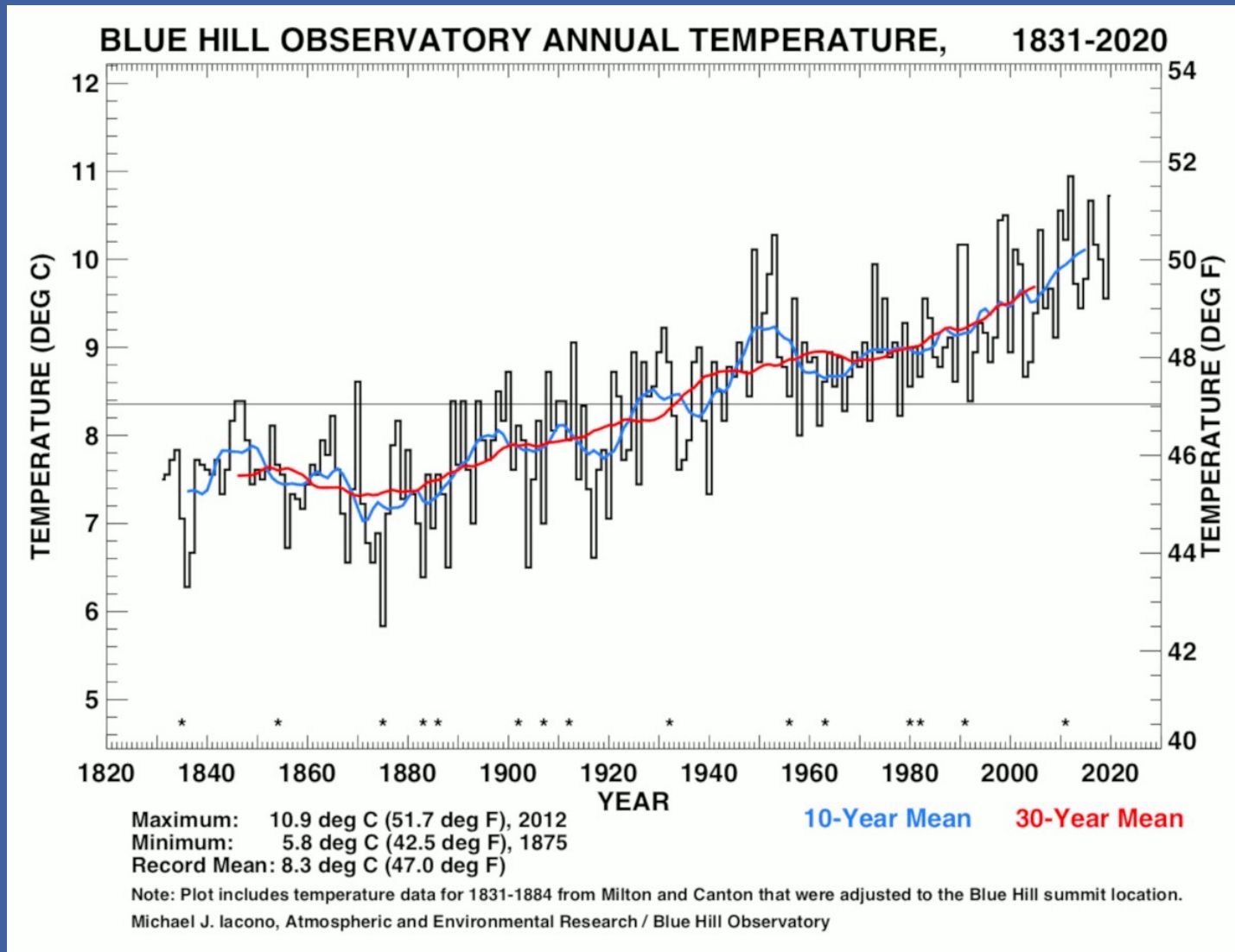
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Thank You!

(Email: miacono@bluehill.org)

BHO Climate: Annual Mean Temperature



- Upward Trend:
+0.32 deg. F/decade,
+4.2 deg. F since 1885
- Trend statistically significant to 99.9% due to:
 - a) Long duration
 - b) Size of trend relative to annual variations
- Volcanic eruptions marked with "*"