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

Michael J. Iacono
Chief Scientist, Blue Hill Meteorological Observatory, Milton, MA
Senior Staff Scientist, Atmospheric and Environmental Research, Lexington, MA

Mount Washington Observatory
Science in the Mountains Webinar
15 June 2021
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

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

Blue Hill Observatory, Great Blue Hill, Milton, MA

1885

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

Wachusett Mountain: 44 miles WNW

Grand Monadnock, NH: 68 miles NW
BHO Climate: Visibility

Images: Reduced Visibility due to Aerosols/Fog/Precipitation

Aerosol Haze over Boston

Heavy Rain Shower

Undercast/Fog
BHO Climate: Visibility

Historic, Hand-Drawn, Distance Charts:

• Survey began 1870, revised in 1886, 1903
BHO Climate: Visibility

Historic, Hand-Drawn, Distance Charts:

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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 µg/m³
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

- 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
• 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**

- 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

- 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

- 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
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 "*"**