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Blue Hill Observatory Sunshine – Assessment of Climate Signals in the Longest Continuous Meteorological Record in North America

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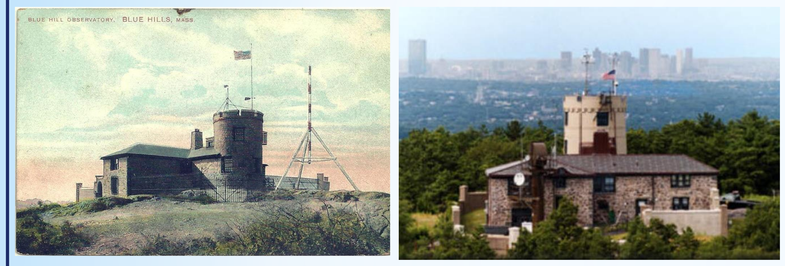
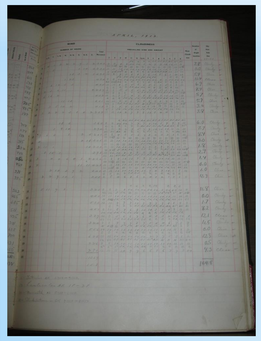
Introduction

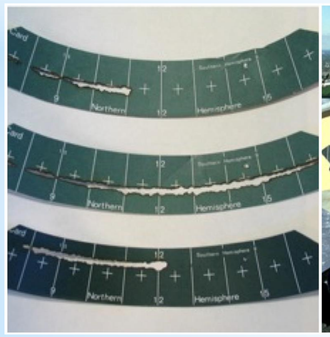
- The Blue Hill Meteorological Observatory is located 10 south of Boston, Massachusetts
- Built in 1885 by Abbott Lawrence Rotch
- It is the longest continuously operating meteorological observatory in the western hemisphere
- The observatory was operated through Harvard University and served as an early home of the American Meteorological Society.
- Meteorological observations and educational programs are now coordinated by the non-profit Blue Hill Observatory Science Center



Blue Hill Observatory ca. 1910 and modern image with downtown Boston in the distance.

- Temperature and precipitation records are digitally availably through the NCDC but do not include the full record of sunshine data using a Campbell-Stokes sunshine recorder
- The Campbell Stokes Sunshine Recorder (image below) consists of a glass sphere mounted concentrically in a spherical bowl, focusing direct solar radiation onto a calibrated paper card, burning a hole
- Burning does not occur during cloud cover (at low irradiance below ~120 W/m^2) and within ~15 minutes of sunset or sunrise
- As the sun moves across the sky, the hole becomes an (interrupted) trace, the aggregate length of which can be used to measure the number of minutes of sunshine occurring over a 24-hour period
- During daylight hours, the trace is analyzed by an experienced observer to determine the duration of bright sunshine in 6 minute increments
- Observatory records include the daily hand-written sunshine analyses from 1888 to present, with greater than 95% completeness. Some of the missing records may yet be recovered from off-site archives

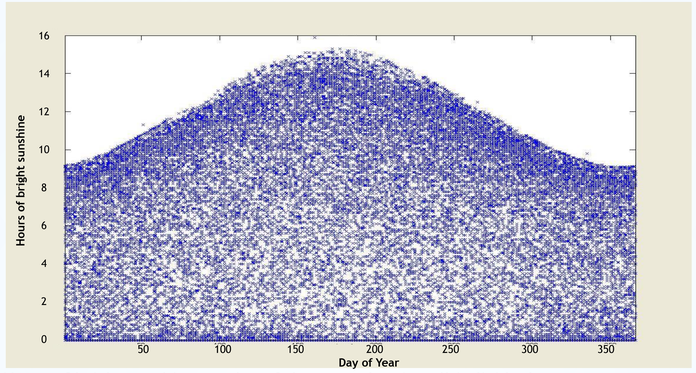




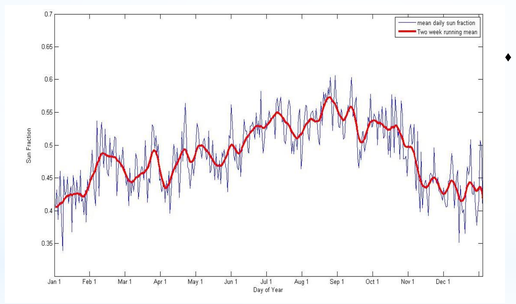
A page of the hand-written daily records from April 1912 (left), examples burns on used trace cards (center) and the mounted Campbell-Stokes sunshine recorder

Methods and Data

- The observatory's original hand-written record books containing first-hand daily observations were digitally photographed and archived
- The daily sunshine records (45290 daily instances) were digitized by hand
- Attempts at optical character recognition (OCR) of the script pencil records were not successful, but advances in OCR technology may permit additional types of ancillary records (e.g. detailed cloud records or hourly temperature data) to be analyzed
- These measurements of daily sunshine represent the earliest and longest continuous instrumental measurement of solar insolation outside of Western Europe
- Daily sunshine durations and frequencies of sunny and cloudy days where statistically analyzed to assess for patterns associated with changing climate and natural cycles

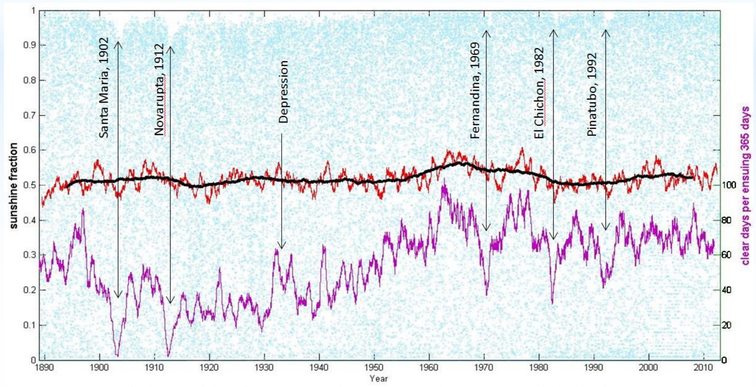


Hours of bright sunshine vs. day of the year, showing all individual measurements



- At Blue Hill, late August through early September sees the highest mean sun fraction while the cloudiest days occur near the beginning of the new year

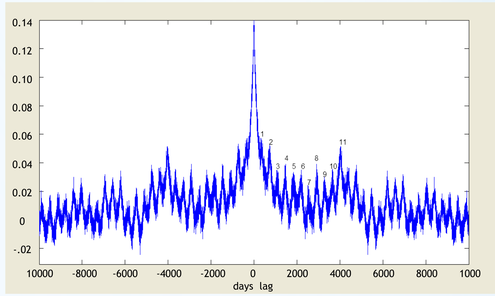
Mean sun fraction vs. day of the year



Long term trends in sunshine fraction (red-1 year moving average, black-10 year moving average) and in number of sunny days per year (purple)

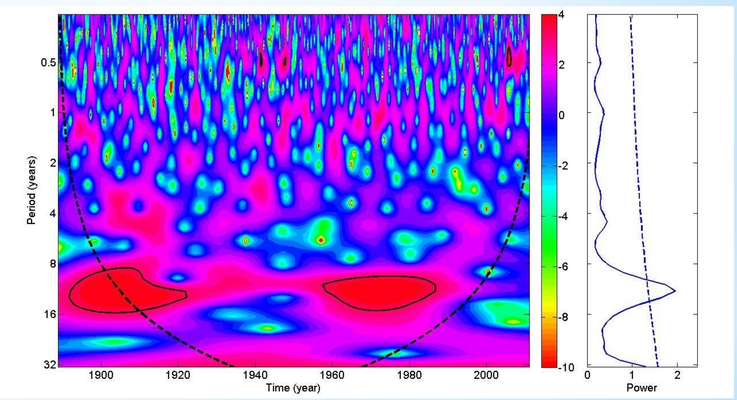
Pattern analyses

- Autocorrletation, cross-correlation, fourier transforms, and wavelet analyses where used to evaluate potential relationships between sunshine amount and other natural and anthropogenic climate signals
- Potential linkages were assessed between observed sunshine and natural cycles of the El-Nino Southern Oscillation, North Atlantic Oscillation, Arctic Oscillation, sun spot number, and galactic cosmic ray incidence. Other connections where evaluated with respect to economic activity and industrialization, regional air quality, incidence of contrail-induced cirrus, and episodes of major volcanic episodes



- Annual cycles of sunny days are readily apparent in autocorrelation analysis. A strong suggestion of an effect from the 11 year solar cycle is also present

Autocorrelation plot of daily incidence of sunny days



Clear days (>92% bright sun) wavelet power spectrum as a function of period and year (left panel) and mean power over the full span of record (right panel). Areas inside solid black lines (left panel) and above dashed blue line are significant at p=.05 level. Annual cycle has been removed by normalization.

Conclusions

- The long and continuous record of daily sunshine enables testing of climatic/sunshine relationships that can not be evaluated with most records. The large number of independent observations allows for statistically significant testing of even weak associations.
- The record clearly reveals the impact of large volcanic eruptions in reducing surface radiation. Long term trends in sun fraction and sunny days also appear to be significantly related to changes in regional air quality and contrail-induced cirrus.
- The 11 year solar cycle is clearly apparent in the sunshine data through multiple types of analysis. The effect appears more likely to be modulated through cloud coverage rather than direct impact of the cycle on radiant flux density. Determination of the mechanism for this effect may have significant climatic implications.
- These analyses are by no means exhaustive -- great potential remains for further research and use of this dataset. The full data set is now freely available at www.bluehill.org