

York River, VA water temperatures as surrogates for historical  
water temperatures elsewhere in Chesapeake Bay, Virginia

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## What the Ancients Knew (With apologies to the History Channel)



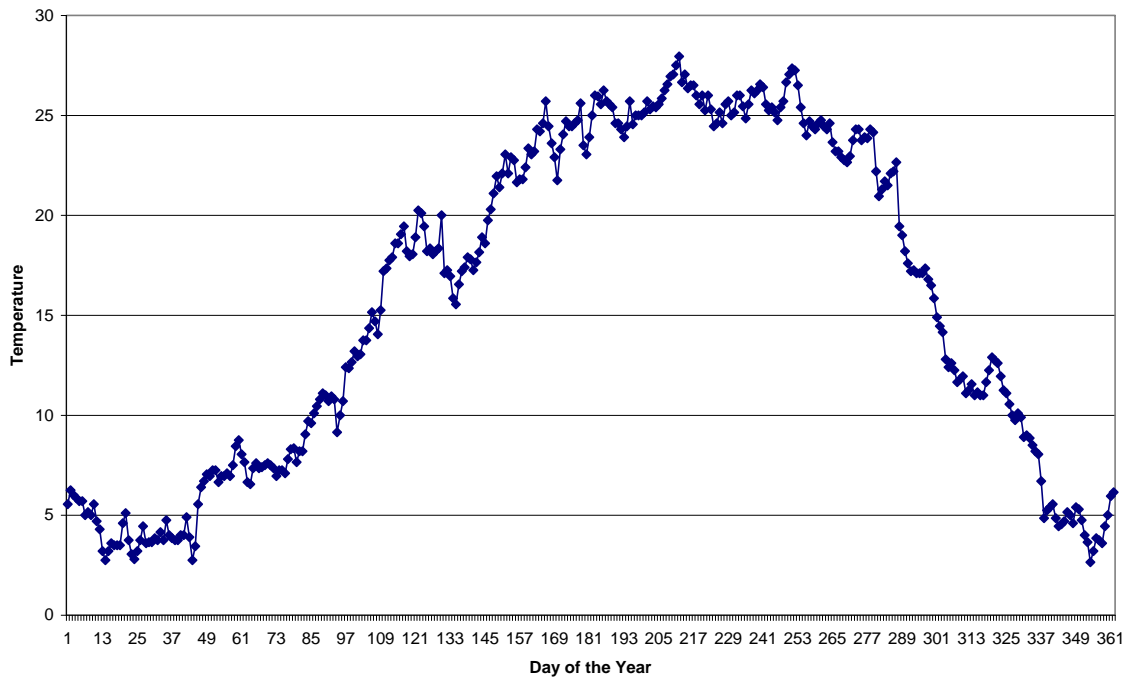
Who knows how many proofs of the Pythagorean Theorem have been published? And certainly, people are working on new ones as we speak. The data I will present today are not earth-shattering, and I will not demonstrate anything that you don't already know. In fact, these facts have been known for millennia. What I have are data you may not have seen before, supporting the facts.

We all know the underlying facts governing the four seasons. The tilt of the Earth's axis of rotation orients one hemisphere towards the sun for half the year as the Earth progresses about its elliptical orbit. At one point in time that hemisphere is pointing directly at the Sun, and that point marks the Summer Solstice, a time when the period of daylight is maximal. The Winter Solstice is similarly determined, and daylight is minimal. The Spring and Fall equinoxes occur midway between the solstices, when the daylight and dark portions of the day are equal. These astronomical observations are fairly easy to make using modern telescopes and clocks.

Easily observed without instruments is the way temperature changes. Surely people paid attention to temperature; they had little choice. Can we determine spring, summer, fall and winter without astronomy?

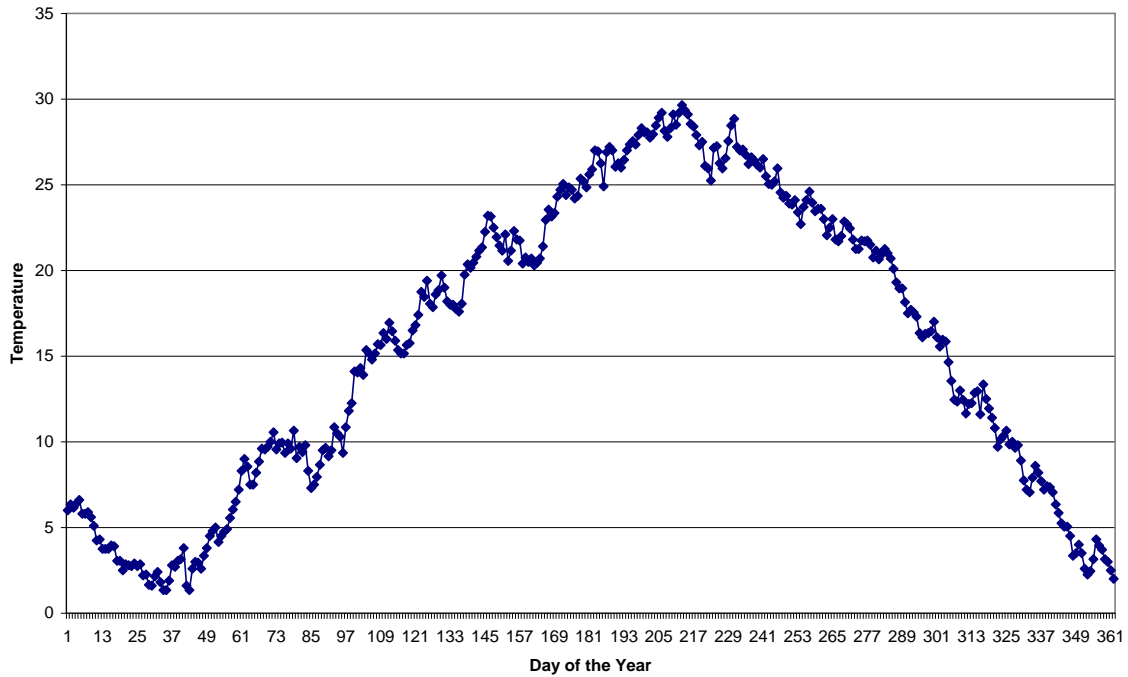
Here is a year of daily observations of water temperature at a depth of two meters in the York River, at Gloucester Point, Virginia. The days are numbered consecutively from January 1, and the y-axis is temperature in degrees Celsius.

Daily Mean Water Temperature, 1954



It's fairly easy to see winter as a period of uniformly cool temperatures, though we're actually seeing half of one winter and half of the next, on the ends of the graph. Following winter on the left the temperature abruptly starts increasing, and increases almost linearly, which is characteristic of spring. Temperature then levels off and we have a period of uniform warmth. Then an almost linear cooling period follows. Using just one year of data and an assumption that the seasons are equal in length, we can describe the four seasons with these data.

Water Temperature, 1955

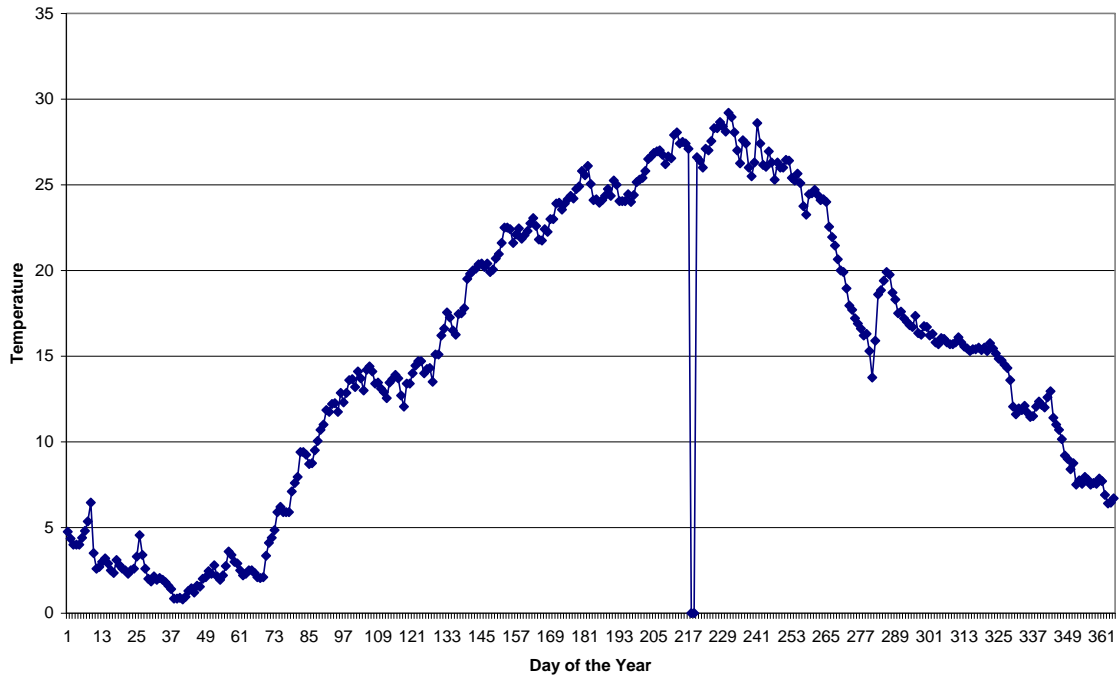


The following year holds no surprises, but by examining two years, one at a time, it's easy to see the difficulty in noting accurate demarcations of the beginning and end of each season. There is too much noise in the data. Water temperatures are more stable than air temperatures, because they change more slowly. Nevertheless, changes in insolation show up, rain changes temperature noticeably, and changes in freshwater discharges further up the watershed are reflected in these data.

The period over which I have data is 1954 - 2001, so here are a few more single years, selected at random. The early years have two observations per day, at midnight and mid-day. Beginning in 1985 new automated equipment was installed that recorded temperature every six minutes. In my analyses, the daily means are used.

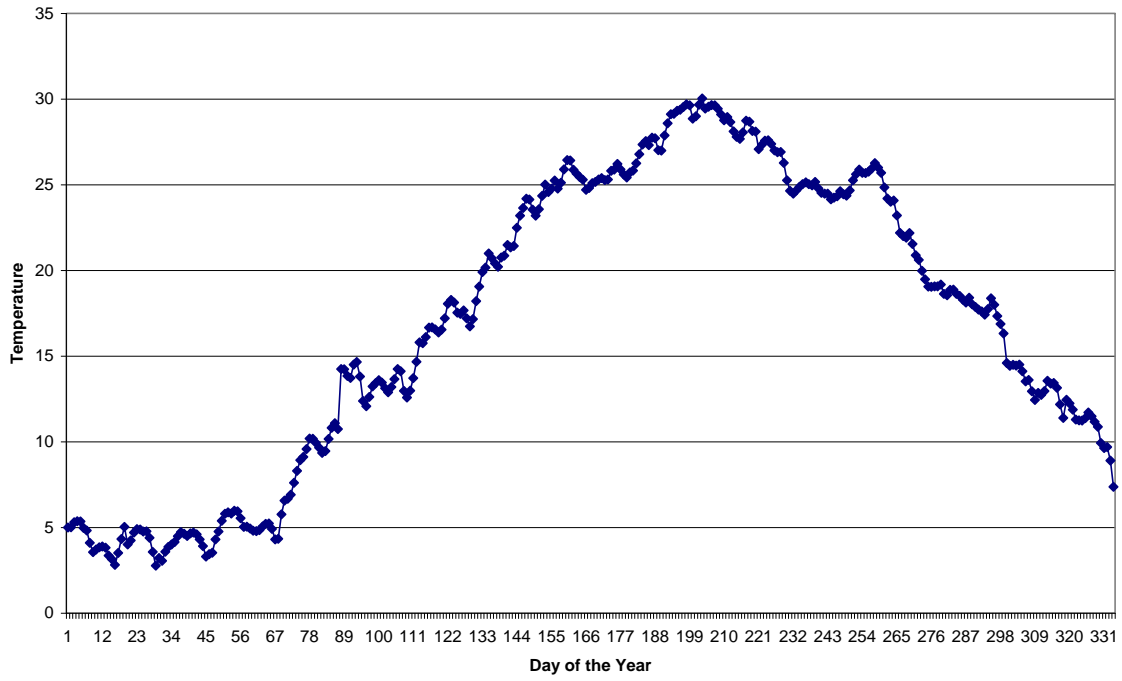
Here an anomalous observation is obvious.

Water Temperature, 1978



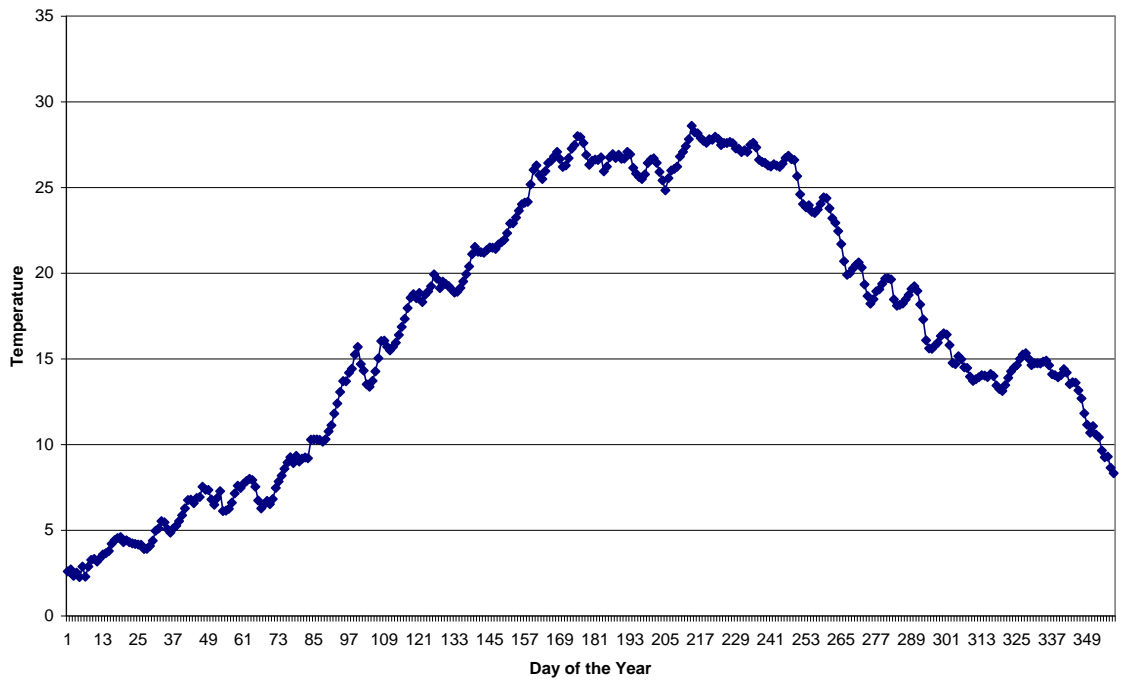
Some transition problems were encountered when moving to the new equipment, resulting in missing data. Indeed, there are intervals scattered through the period of record where problems occurred, such as major storms (Hurricane Agnes was one), or equipment simply failed. 1986 is the first year of good six-minute data, and there are still some missing observations.

**Water Temperature, 1986**

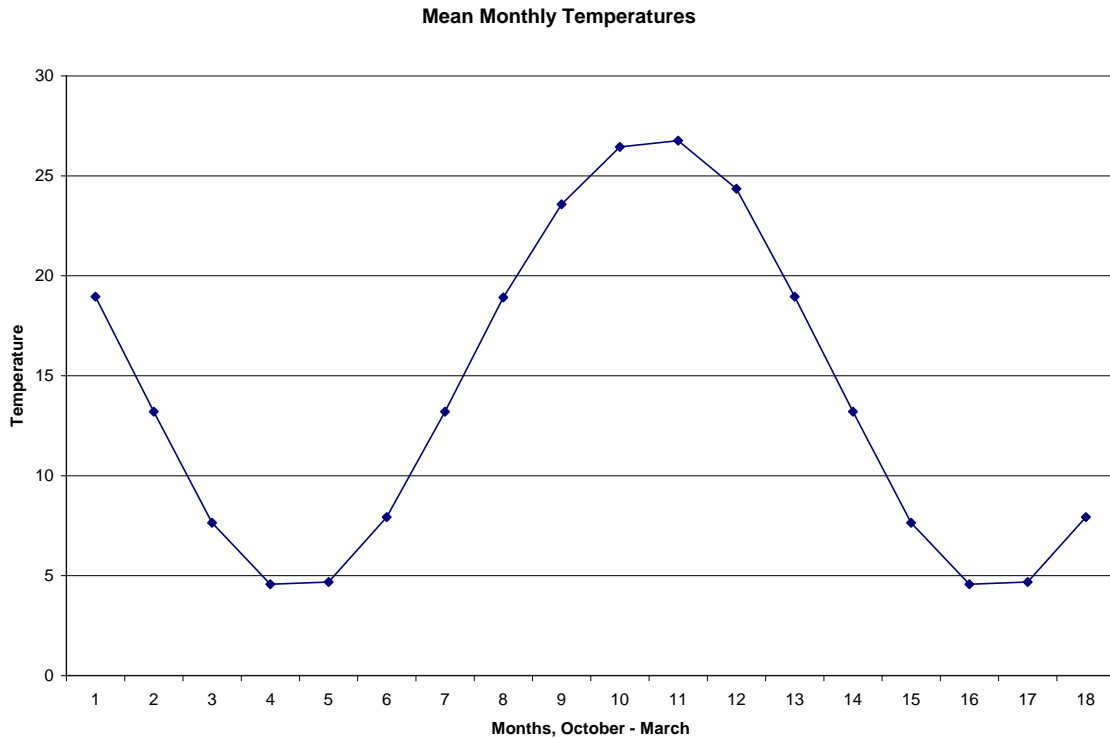


2001 is the last year for which I have data.

**Water Temperature, 2001**

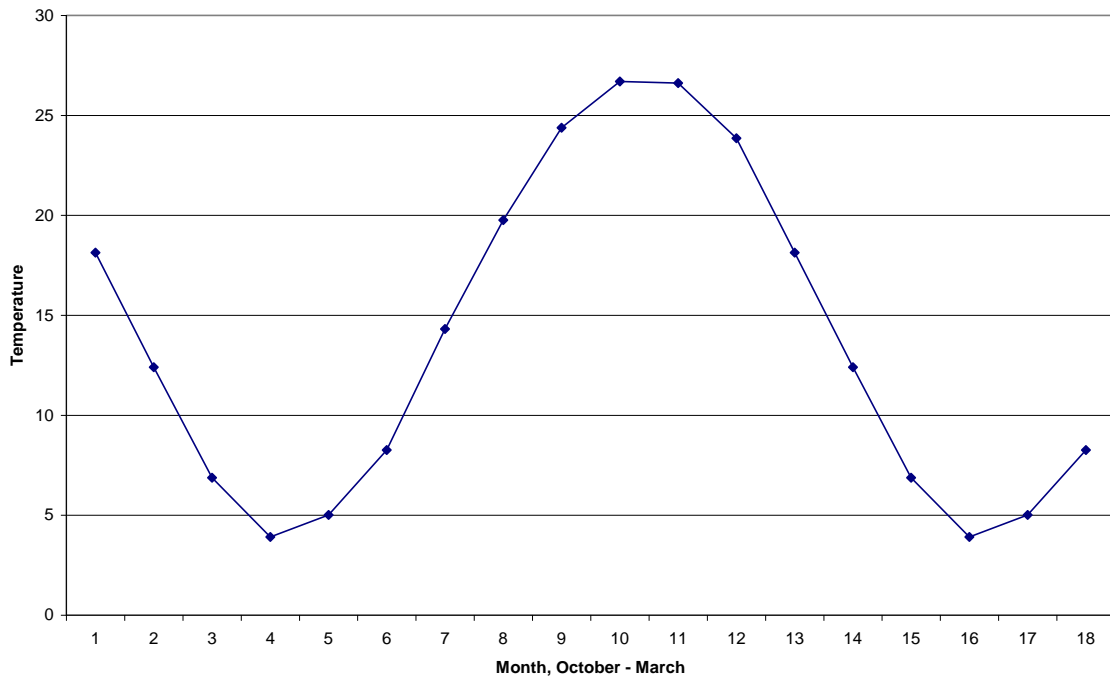


If we look instead at monthly means, the problem comes much closer to a solution. Months are unequal in length, so there is a touch of ambiguity, but the month in which a season begins and ends is obvious. I have appended a few months at each end so an entire cycle is clearly visible. The third month from the left is December, and from December to March we see a period of cold that is winter. Starting in March the near linear increase in temperature over time is spring. June starts summer, which end in September, and the following three months are fall.



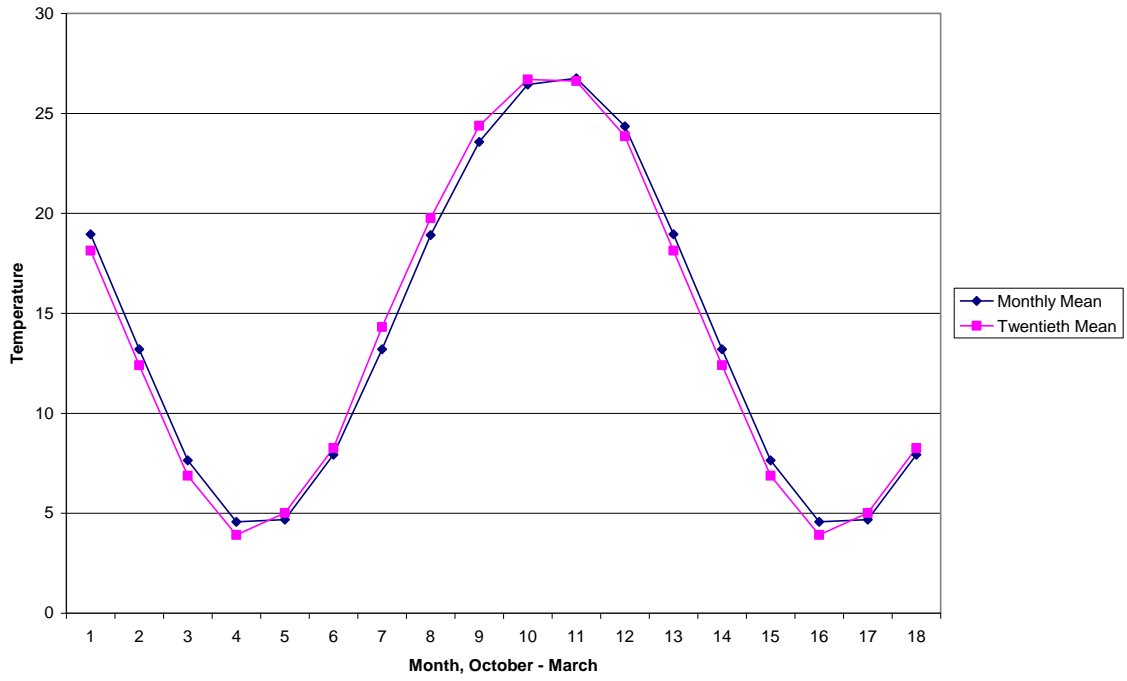
A more precise description can be made using the mean temperatures on the dates of the four events, the solstices and equinoxes. The dates move about just a little, from year to year. This year, for example, the dates are March 20, June 20, September 22, and December 21. Just as a matter of convenience, I chose the twentieth of each month and calculated the mean temperature for the period of record. The dates of the solstices and equinoxes are easily seen.

Twentieth of the Month Mean Temperature



Just as a matter of interest, the final image places the monthly means and the twentieth of the month means on the same figure. It appears that the monthly mean temperatures, which are available at rudimentary levels of technology, mark the beginning of each of the four seasons very well.

Monthly and Twentieth Means



Daily Means, 1954 - 2002

