

A Solar-Cycle Influence on New England's Climate?

Richard Wolfson, Department of Physics, Middlebury College, Middlebury, VT USA

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Abstract

This year's SORCE meeting site inspires a search for solar-cycle influence on New England's climate. The dataset used combines individual station data for 73 New England and New York (NE-NY) stations of the Historical Climatology Network with continuous data for the period 1903 through 2000. I construct a function consisting of sequential sinusoids whose periods are the (varying) solar-cycle lengths observed for the twentieth century; Fourier transforming this function yields a broadened peak centered at approximately on the mean cycle length of 10.65 years. Transforming the NE-NY temperature data gives a feature with similar shape at the same place in frequency space. Correlation between the two transforms in the region of this feature is some 95 percent. A Monte-Carlo simulation shows that a correlation this high occurs at random with a probability of only about 0.1%. Three other analyses provide modest support for the notion that this analysis has identified a real solar-cycle influence. However, questions about the statistical methodology and especially about the amplitude of the solar-cycle influence cast serious doubt on the apparent result.

Disclaimer

The author of this poster is a theorist specializing in magnetohydrodynamics of the solar corona. Statistical analysis of data is not part of my regular research experience. The statistical methodology used here is novel and questionable, so the author invites comments on the method and on possible significance of the results. A statistician consulted in connection with the method used here was unable to draw a firm conclusion about its validity or interpretation.

The Data

Data for 1903-2000 is averaged for 73 New England and New York (NE-NY) stations of the Historical Climatology Network (HCN; see Trombulak & Wolfson 2004). Three versions of this data are analyzed, all with linear trend subtracted and mean set to 0: (1) a 392-point timeseries of seasonal temperatures for the 98-year period, (2) a 98-point timeseries of HCN annual temperatures, and (3) a 98-point timeseries comprising the averages of the four seasonal temperatures. The work reported here uses timeseries (3). Results for the other two timeseries give very similar results.

Controversy!

I am well aware of the controversy surrounding the solar-cycle lengths (SCLs) used by the authors cited herein (see Damon & Laut 2004, Laut & Gunderman 1998, and Mursula & Ulich 1998). Since I use unfiltered SCLs, this work is not subject to the criticism of Damon & Laut (2004). But, as Mursula & Ulich (1998) point out, determination of unfiltered SCL is fraught with ambiguity. Indeed, Mursula & Ulich (1998) have introduced a so-called "median method" that should be significantly more accurate. I have repeated the analysis described here using their median SCL values, and find similar results with somewhat less statistical significance ($p=0.006$ versus $p=0.0008$).

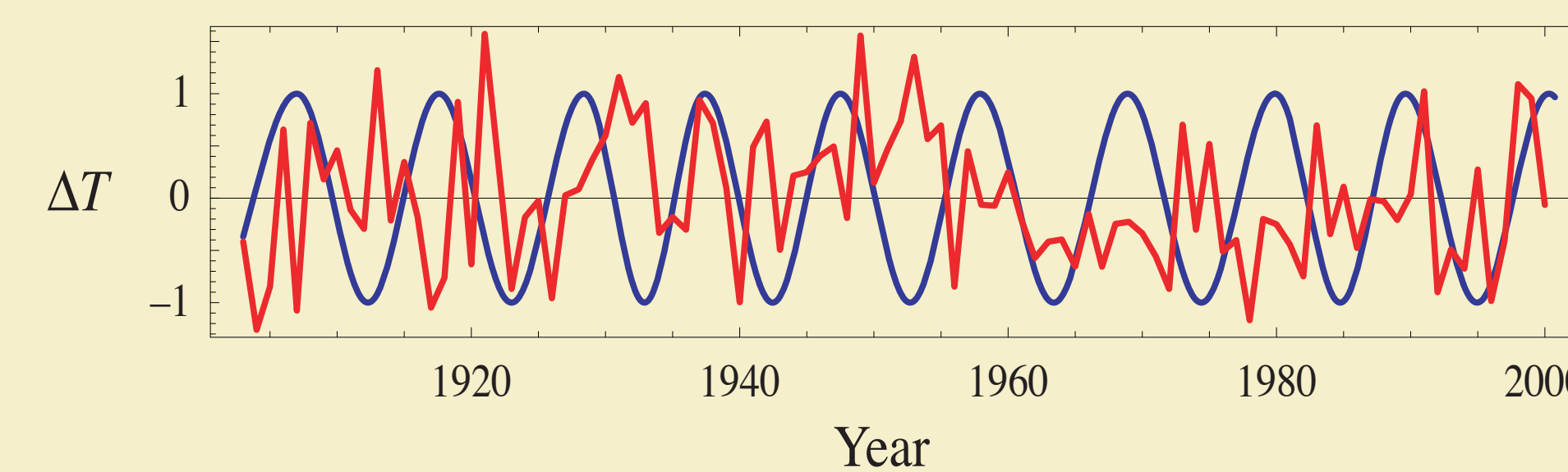
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A Naïve Approach

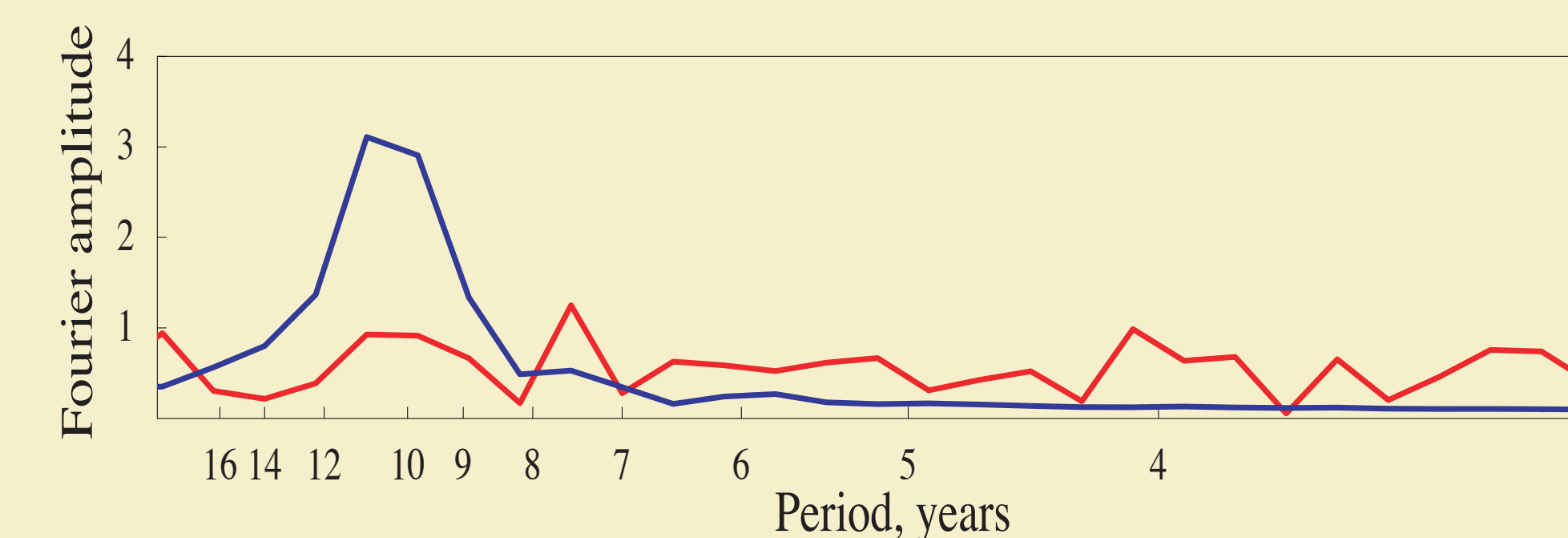
Confirming solar-cycle influences on climate is a subtle science. History is replete with bogus reports of correlations between the solar cycle and all sorts of quantities from the stock market to political trends. A recent study by North et al. (2004) uses multivariate regression to extract a solar-cycle signal in the global climate, with a significance level of about 25 percent. The apparent climate variation over the solar cycle amounts to only a few hundredths of a kelvin.

A more naïve approach is to Fourier transform climate data and look for peaks at the solar-cycle frequency. This is the approach used here, with one important refinement. The length of the solar cycle is not constant, but has varied significantly over the course of the twentieth century. I have therefore constructed a test function consisting of successive sinusoids, each with the appropriate period, covering the interval from 1894 through 2000 and thus overlapping our data. I use the unfiltered periods given by Friis-Christensen & Lassen (1991) as updated by Thejll & Lassen (2000); see **Controversy!**, at left.



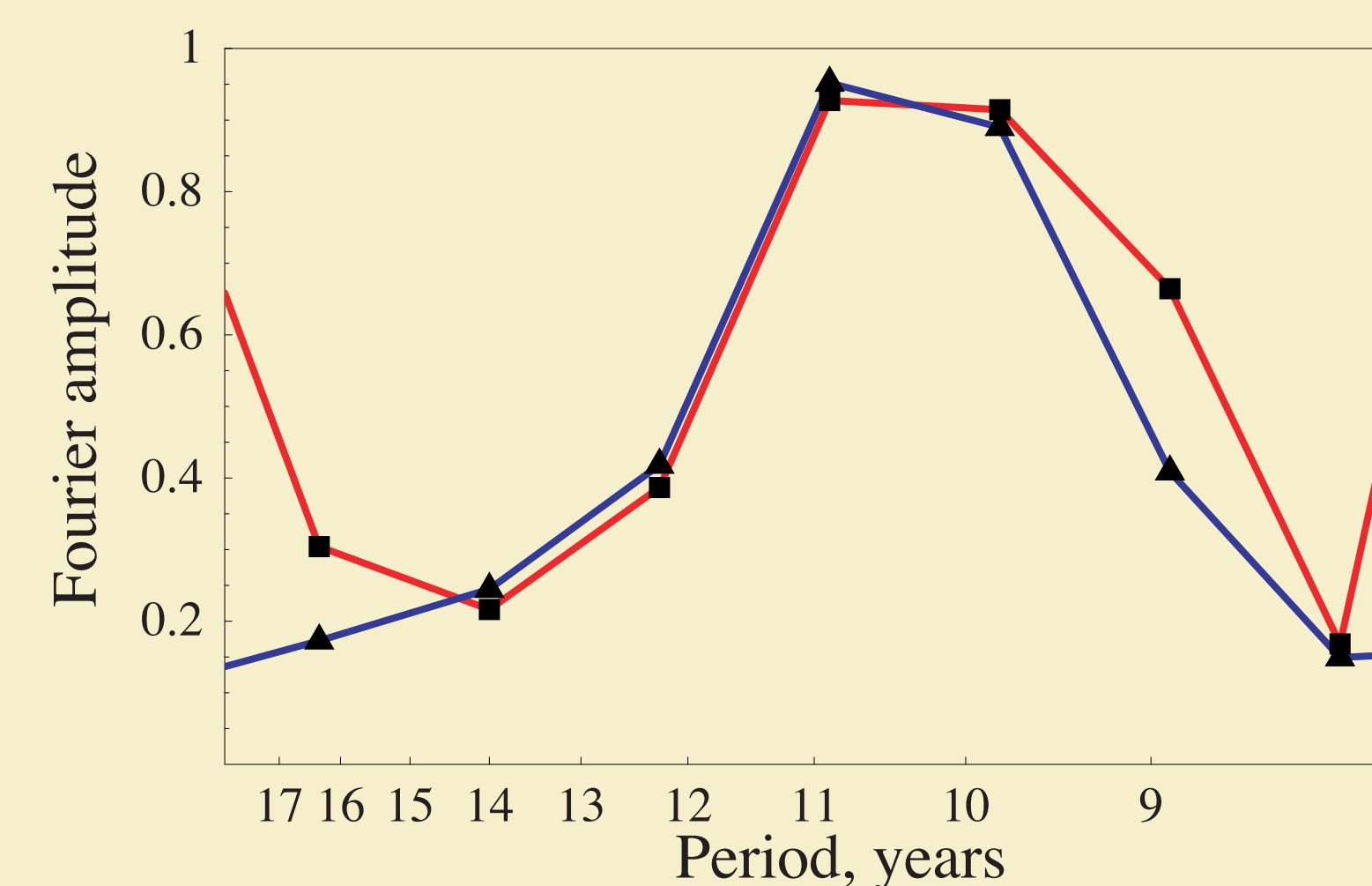
Data and test function for the 98-year period, with ΔT in $^{\circ}\text{C}$

The test function is sampled to produce a 98-point timeseries, and its discrete Fourier transform is computed; the result is a broad peak instead of the narrow spike one would get from a fixed period. The Fourier transform of the data is compared with the transform of the test function. Both show features centered approximately on the average SCL. The data feature, however, is comparable in amplitude to the surrounding noise.



Fourier transforms of data and test function

A closer look shows a limited portion of frequency/period space, with the two features scaled to same height. Correlations are computed on the 7 marked points. Correlation between data and test function is 0.95.



Acknowledgments

I thank Frank Winkler, Jeff Duinham, Noah Graham, and especially John Emerson for their discussions and numerous helpful suggestions.

A Problem of Large Amplitude

A major objection to this poster's suggestion of a possible solar-cycle influence on the NE-NY climate is the scaling needed to make the variable SCL test function's Fourier amplitude equal to that of the feature observed in the Fourier transform of the data. The plot of the data and test function (at left) in the time domain shows the test function arbitrarily scaled to have amplitude 1°C . Its peak in the Fourier transform is then about 3 times larger than the corresponding feature in the data transform. So the test function, representing the solar-cycle variation in temperature, needs to be scaled down by a factor of about 3. The exact scaling sets the required solar-cycle amplitude at 0.3°C . But that's roughly an order of magnitude greater than the "few hundredths of a degree C" found by North et al. (2004). Specifically, North et al. show global contours of solar-cycle response amplitude; for the northeastern United States, that amplitude is around 0.04°C . Worse, that 0.3°C is a peak amplitude; the peak-to-peak variation is twice this. There is no good physical reason to expect such a large climatic response to the solar cycle.

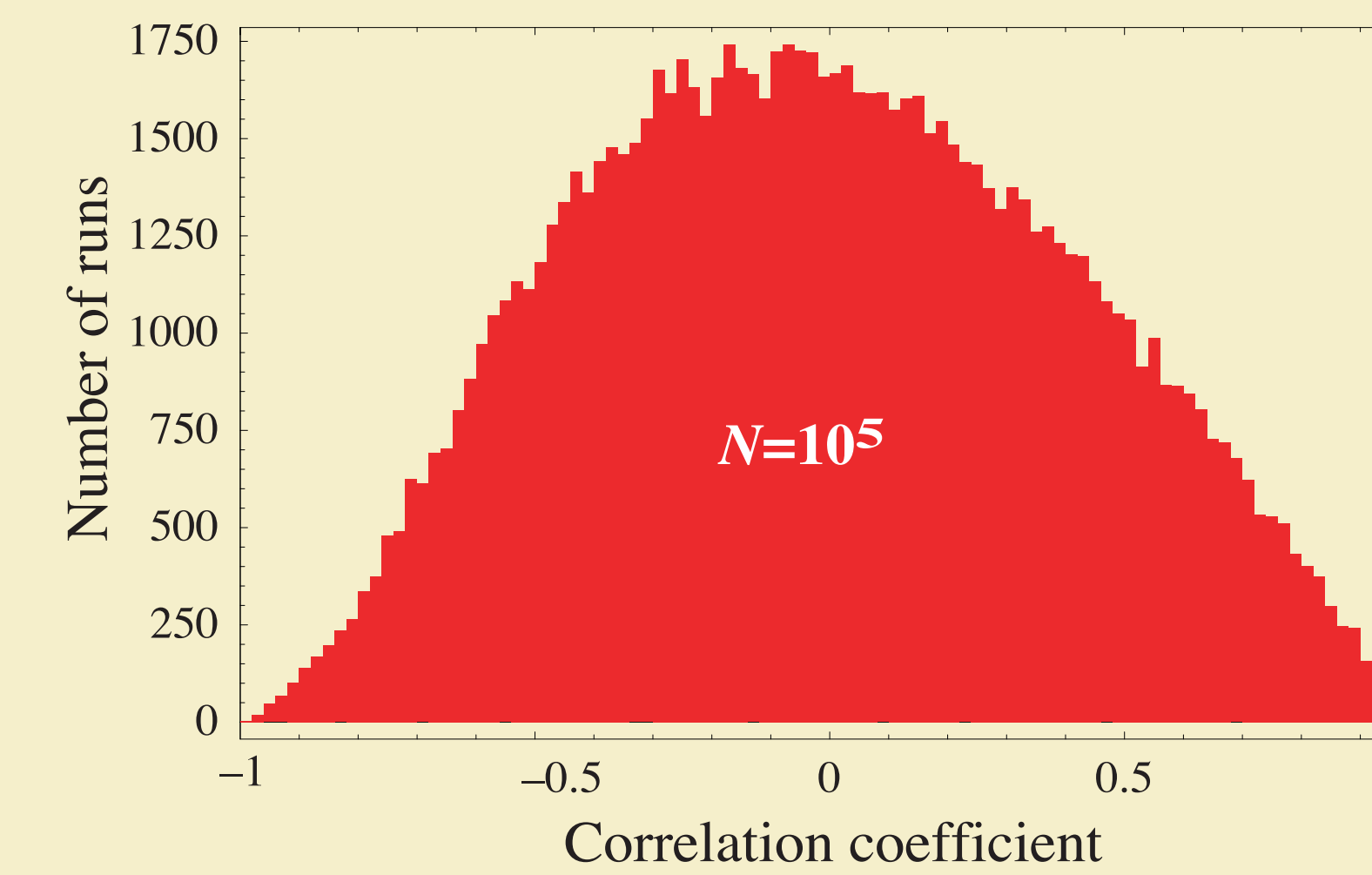
Conclusion

Taken at face value, the Monte Carlo simulation described here seems to suggest a solar-cycle feature in the Fourier transform of the twentieth-century NE-NY climate, a feature unlikely to be there by chance (significance $p \sim 0.001$). Additional tests provide some corroboration, but are not particularly convincing. And the required amplitude of the solar influence is an order of magnitude too high to be physically reasonable.

Furthermore, it is unclear to this theoretician author, and to the statisticians he consulted, how the analysis of correlation in the frequency domain translates stastically into the time domain.

What do you think? Comments below, please!

A Monte Carlo simulation produces 10^5 Gaussian random timeseries. The Fourier transform of each is correlated with the Fourier peak of the test function, shown in the previous figure. The results are shown in the histogram below:



A histogram of the correlations. Just under 0.1 percent—fewer than 1 in 1000—of the random timeseries have correlation coefficients exceeding the value 0.95 associated with the Fourier transformed temperature timeseries. **Does this mean the feature in the Fourier transform of the data is likely to represent a real solar influence on temperature?**

Three More Tests

(1) I construct artificial data consisting of Gaussian noise plus the variable SCL test function, with the standard deviation of the noise equal to that of the data. The analysis method described above is applied to the artificial data, doing a 1000-sample Monte Carlo simulation. I repeat this whole procedure for 50 such artificial signals. For this ensemble, the mean correlation between the artificial, noisy signal (which is known to contain a solar-cycle variation) and the Fourier transform of the SCL test function is 0.85, for a 1.8% chance that the correlation is random. This suggests that the method is indeed capable of extracting a solar-cycle signal if present in the data.

(2) The variable SCL test function is subtracted from the data, to see if this reduces the correlation between Fourier transforms. The correlation drops from 0.95 to 0.28. When the same subtraction is done for 1000 Gaussian random timeseries, the average correlation increases slightly—not surprising because a solar-cycle signal has been injected into what was a truly random timeseries. This effect occurs even if the phase of the subtracted SCL function is varied.

(3) An autocorrelation analysis is performed on the data. Four or five obvious peaks emerge, as shown below. One is at 9 years, one of our solar-cycle lengths; another is at 22 years, the sum of two adjacent 11-year cycles. The other peaks seem unrelated to SCLs.

