Problem 5.1.

The file `atacama-hourly-sample.csv` contains hourly measurements from various sensors from the Atacama desert in Chile. The sensors c3 and c4 measure the CO\(_2\) concentration in part per million (ppm), uncorrected for the high altitude (Atacama is at 16,000 ft, and the air pressure is about half of the sea-level one). The columns t5 and t6 are the outside temperature from two sensors in °C. The time is displayed in different granularities (hours from the beginning of the experiment, hours within each day (dhours), days from the beginning of the experiment. There is a glitch in the CO\(_2\) sensor values on day 70, ignore those values (set them to 0). The expression below defines the cross-correlation between two different time-series \(a\) and \(b\).

\[
C_{ab}(\tau) = \frac{1}{N} \sum_{t} (a(t) - \langle a \rangle)(b(t + \tau) - \langle b \rangle)
\]

Here \(N\) is the number of measurements included in the sum, \(\langle a \rangle\) and \(\langle b \rangle\) are the averages of the two series.

a. Consider the time series of the two temperature sensors. Break these into daily vectors, and compute the top 3 principal components. Guess the meaning of each component. Expand each vector on the basis of the top 3 components. Estimate the fraction of variance contained in the three components. Estimate the truncation error due to using three components only. Display the amplitudes of the components as a function of time during the observations.

b. Repeat the above with 5 components and compare.

c. Compute the temporal autocorrelation function of both the average of the two hourly temperature and the average of the two hourly CO\(_2\) concentration, out to a difference of 48 hours. Interpret the result.

d. Compute the temporal cross-correlation function between the average temperature and the average CO\(_2\) concentration, out to 48 hours. Discuss the meaning of the result.

Problem 5.2.

Calculate the frequency spectrum of the following signals, sampled at 44.1kHz:

a. Guitar sounds given in the two files `nylon16b.wav` and `strat16b.wav`. Determine the frequency of the fundamental for both sounds.

b. Calculate the relative energy of the first 3 harmonics

c. Estimate the decay time of the third harmonic

Hint:

```python
from scipy.io import wavfile
samplerate, data = wavfile.read(cpath+'strat16b.wav')
```

Problem 5.3.

A die is rolled 24 times. Use the Central Limit Theorem to estimate the probability that

a. The sum is greater than 84

b. The sum is equal to 84

c. Perform a hundred numerical realizations to illustrate the result