

Time Series

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- 1 Introduction
 - Definition
 - Examples

- Informal
 - Data varying over time
- Formal
 - Stochastic process indexed on time

$\{X_t\}$

- Finance Sector
 - Quarterly earnings per share for the U.S. company Johnson & Johnson
 - Figure 1.01
 - 84 quarters: first quarter of 1960 - last quarter of 1980

- Note:
 - gradually increasing underlying trend
 - regular variation superimposed on the trend that seems to repeat over quarters.

- Finance Sector (contd.)
 - Daily returns (or percent change) of the New York Stock Exchange (NYSE) from 2nd Feb, 1984 to 31st Dec, 1991.
 - Figure 1.04

- Note:
 - mean of the series appears to be stable with an average return of approximately zero
 - the volatility (or variability) of data changes over time

- Environmental Science

- The global mean land-ocean temperature index from 1880 to 2009, with the base period 1951-1980
- Figure 1.02
- Plot of deviations, measured in degrees centigrade, from the 1951-1980 average

- Note:
 - apparent upward trend in the series during the latter part of the twentieth century
 - Is it unusual

- Environmental Science (contd.)
 - Monthly values of an environmental series called the Southern Oscillation Index (SOI) and associated Recruitment (number of new fish)
 - The SOI measures changes in air pressure, related to sea surface temperatures in the central Pacific Ocean
 - Both series are for a period of 453 months ranging over the years 1950-1987.

- Note:
 - Both series tend to exhibit repetitive behavior
 - The cycles of the SOI are repeating at a faster rate than those of the Recruitment series.
 - The Recruitment series also shows several kinds of oscillations, a faster frequency that seems to repeat about every 12 months and a slower frequency that seems to repeat about every 50 months.
 - Two series also tend to be somewhat related; it is easy to imagine that somehow the fish population is dependent on the SOI.

- Physical Science

- A small .1 second (1000 point) sample of recorded speech for the phrase *aaa... hhh*,
- Figure 1.03

- Note:
 - repetitive nature of the signal and the rather regular periodicities.

- Medical Science

- Data collected from various locations in the brain via functional magnetic resonance imaging (fMRI).
 - five subjects were given periodic brushing on the hand.
 - stimulus was applied for 32 seconds and then stopped for 32 seconds; thus, the signal period is 64 seconds.
 - sampling rate was one observation every 2 seconds for 256 seconds ($n = 128$).
 - averaged result over subjects
- consecutive measures of blood oxygenation-level dependent (bold) signal intensity, which measures areas of activation in the brain
- Figure 1.06

- Note:
 - the periodicities appear strongly in the motor cortex series and less strongly in the thalamus and cerebellum.

- Earth Science

- The recording instruments in Scandinavia are observing earthquakes and mining explosions
- Two phases or arrivals along the surface, denoted by $P(t = 1, \dots, 1024)$ and $S(t = 1025, \dots, 2048)$, at a seismic recording station
- Figure 1.07

- Note:
 - amplitude ratios of the first phase P to the second phase S, which tend to be smaller for earthquakes than for explosions.
 - a subtle difference exists in the periodic nature of the S phase for the earthquake

- Two dimensional time-series
 - temperature series x_{s_1, s_2} that represent positions on a 64×36 spatial grid set out on an agricultural field.
 - Figure 1.17

- Correlation introduced by sampling of adjacent points in time
 - Break assumption: i.i.d. errors
- Needs special techniques
- Two approaches of Time Series Analysis
 - Time domain
 - Frequency domain