

Fitting time series models, Part 2

CIHR Course Week 3

Isabel (Izzie) Fulcher

isabel_fulcher@hms.harvard.edu



Teaching Objectives

- Quick recap of time series modeling from Part 1
- Seasonality and time trends
- Syndromic surveillance
 - Motivation
 - Steps
 - Group activity
 - Prediction intervals



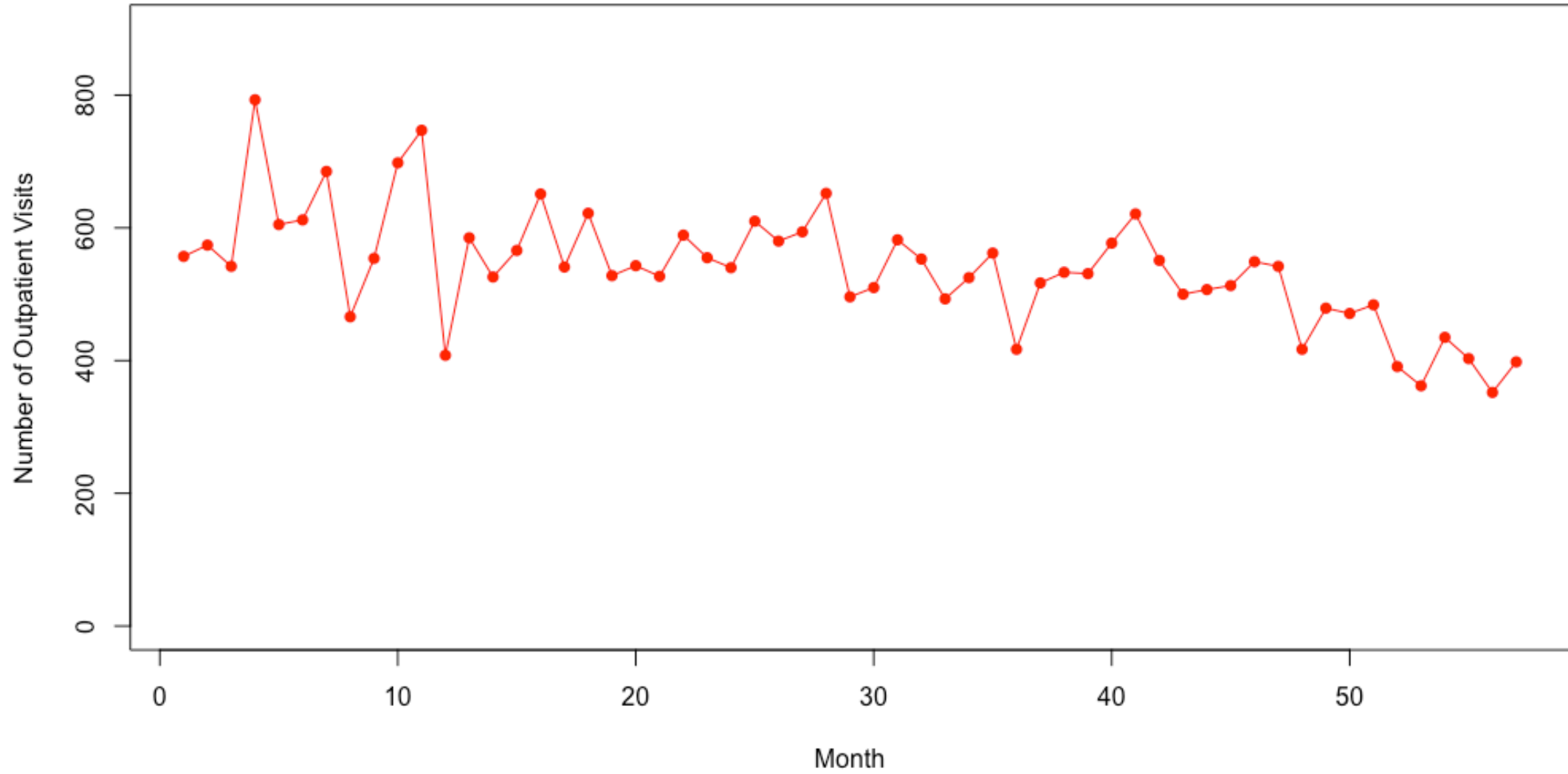
Part 1 Recap

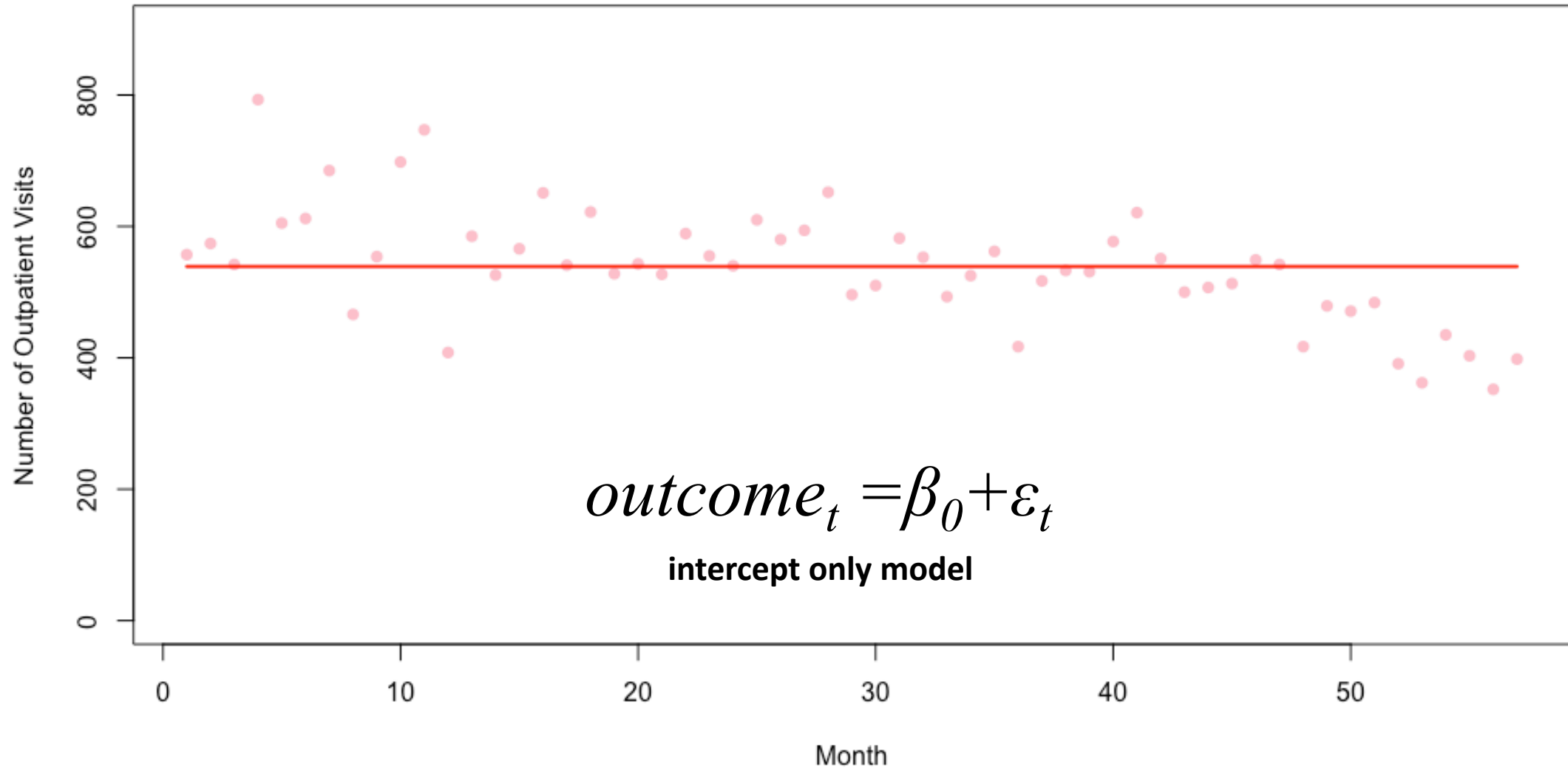


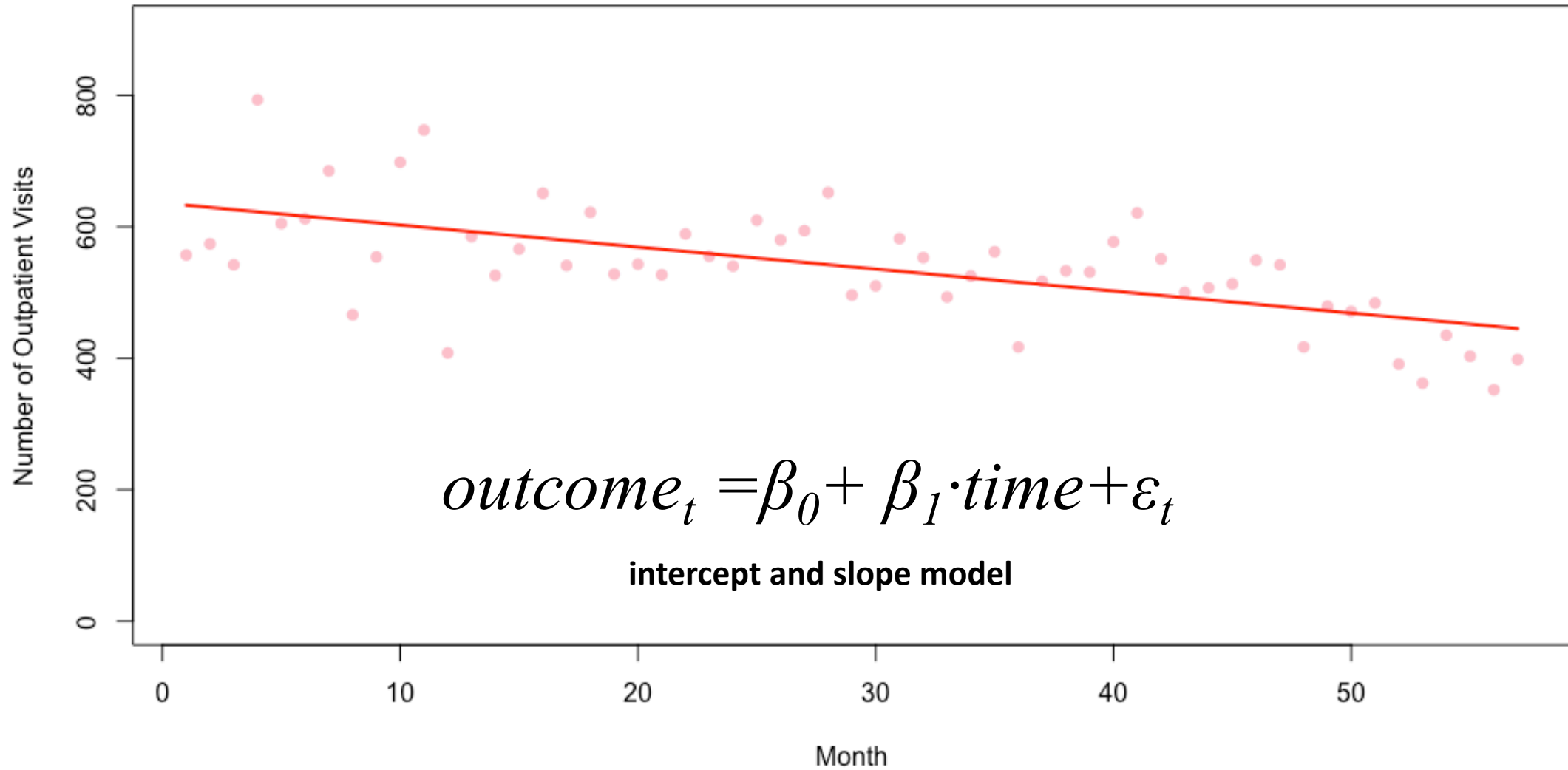
Research questions with time series data

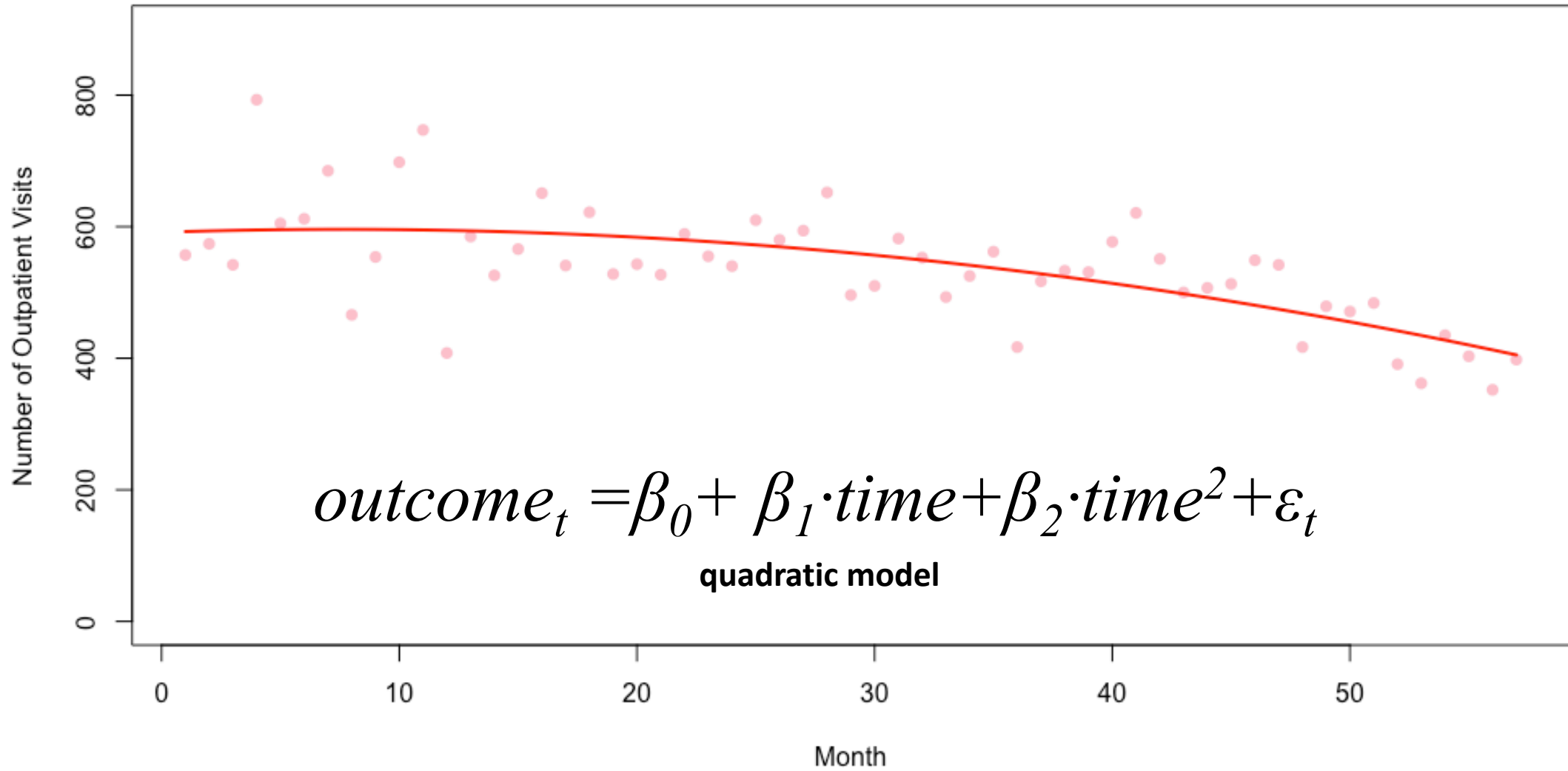
- **Describe** the behavior of an indicator over time
 - Is infant mortality decreasing over time? By how much?
 - What are the seasonal differences in malaria cases?
- **Detect** deviations from expected in an indicator
 - Is a region experiencing higher than expected cases of diarrhea?
 - Is the number of health facility deliveries lower than expected?
- **Measure** the impact of an intervention on an indicator
 - After social distancing measures were put in place, how many fewer COVID-19 cases were there?





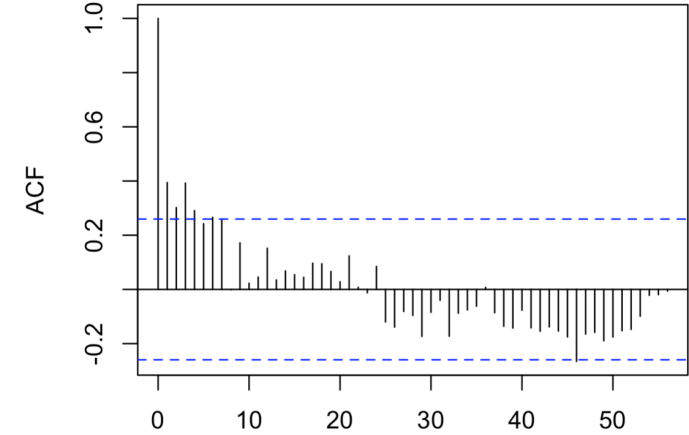
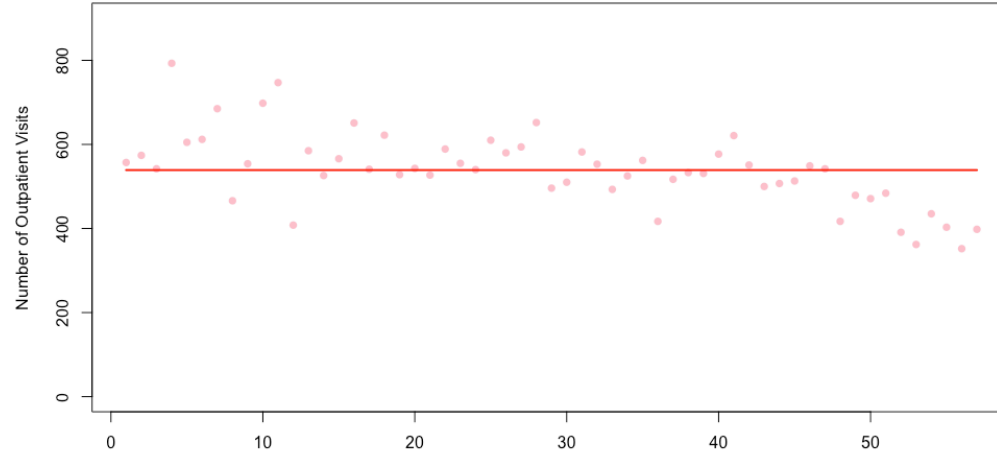




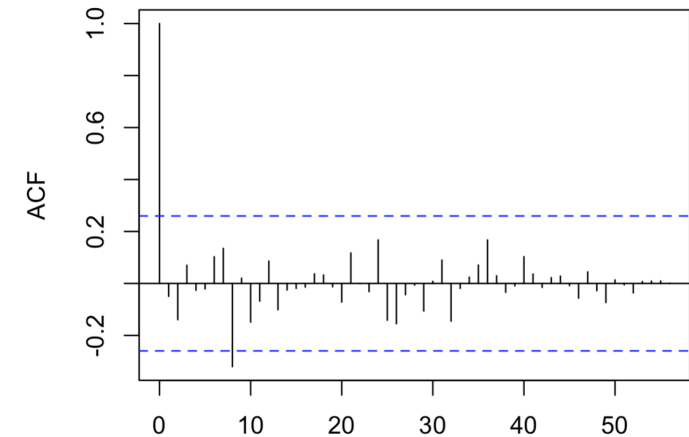
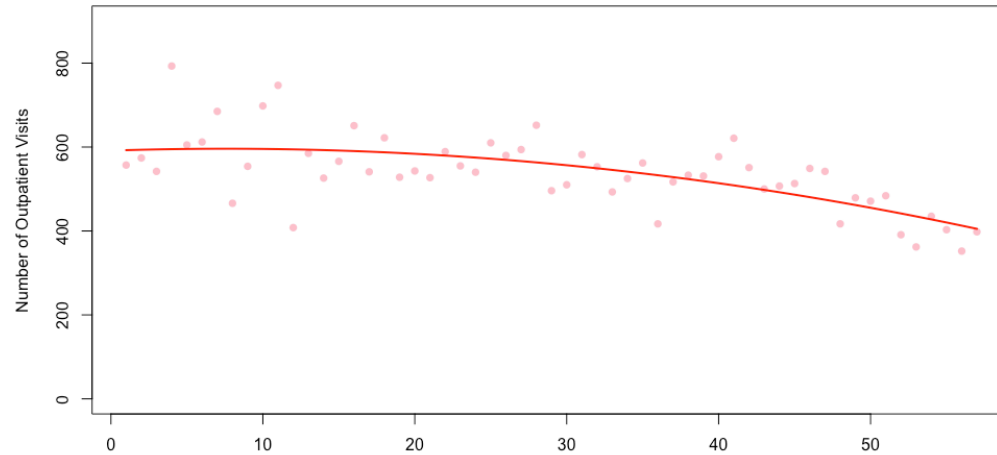


Model diagnostics: autocorrelation

**intercept only
model**



**quadratic
model**



Seasonality and time trends



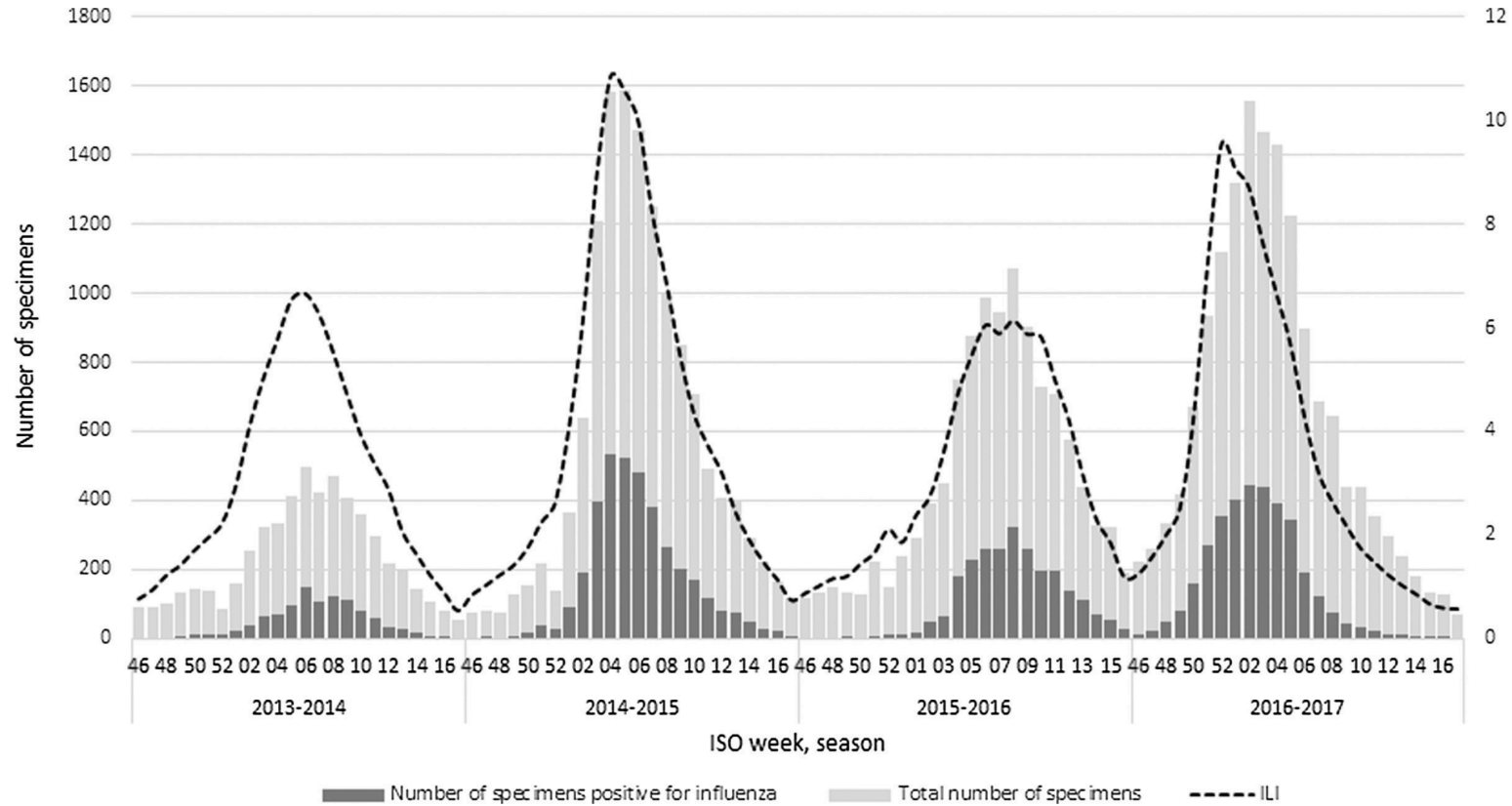
Time series patterns

- **Seasonal:** Outcomes are impacted by seasonal factors (season, month, day of the week)
 - Fixed with known frequency
 - Easily mistaken with fluctuations (must be related to some aspect of calendar time)
- **Trend:** Long-term increase or decrease in the data.
 - Trends can change direction over time
 - Trends do not need to be linear

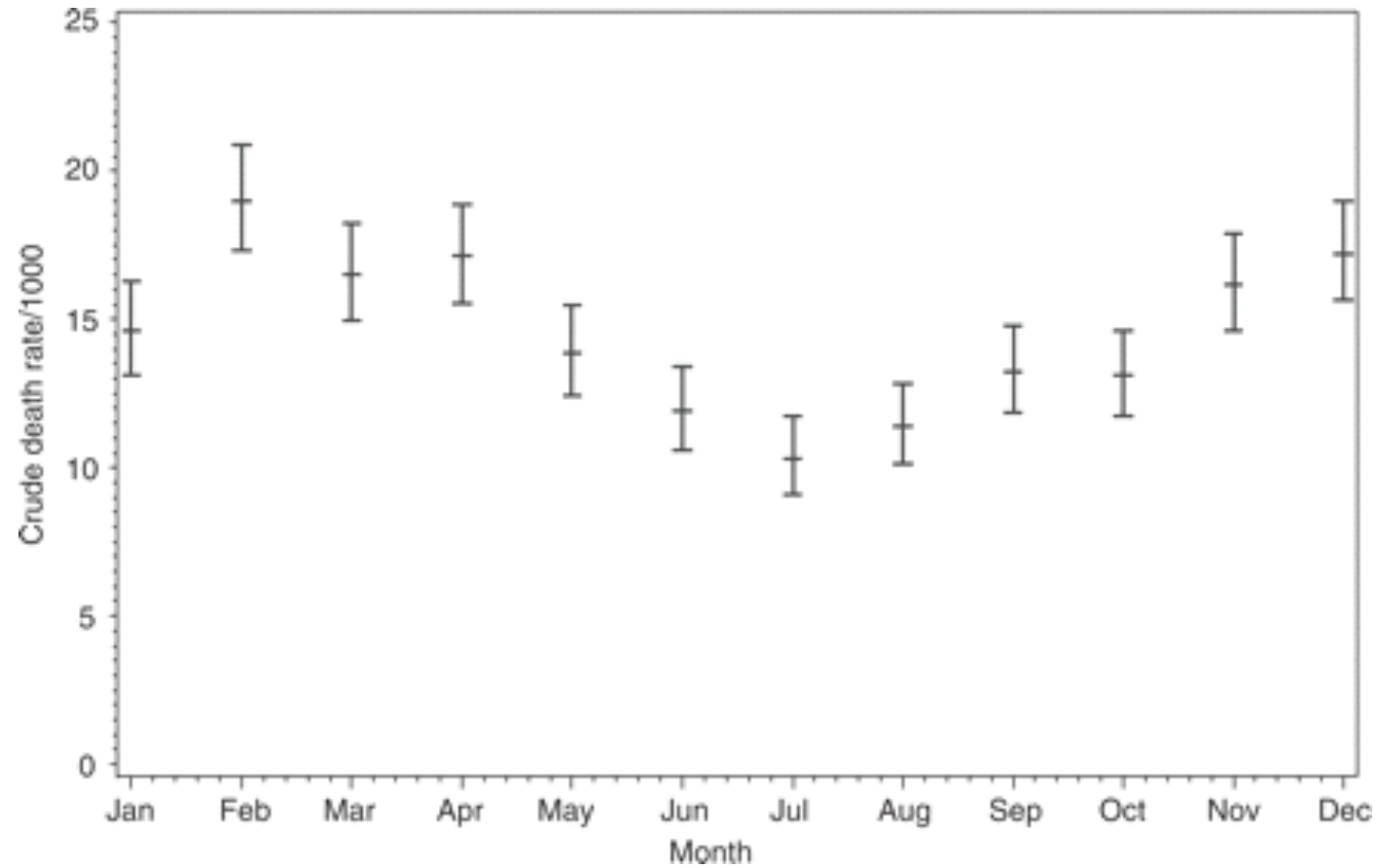
Source: Forecasting: Principles and Practice (<https://otexts.com/fpp2/>)



Influenza in Italy (Rosano et al., 2019)

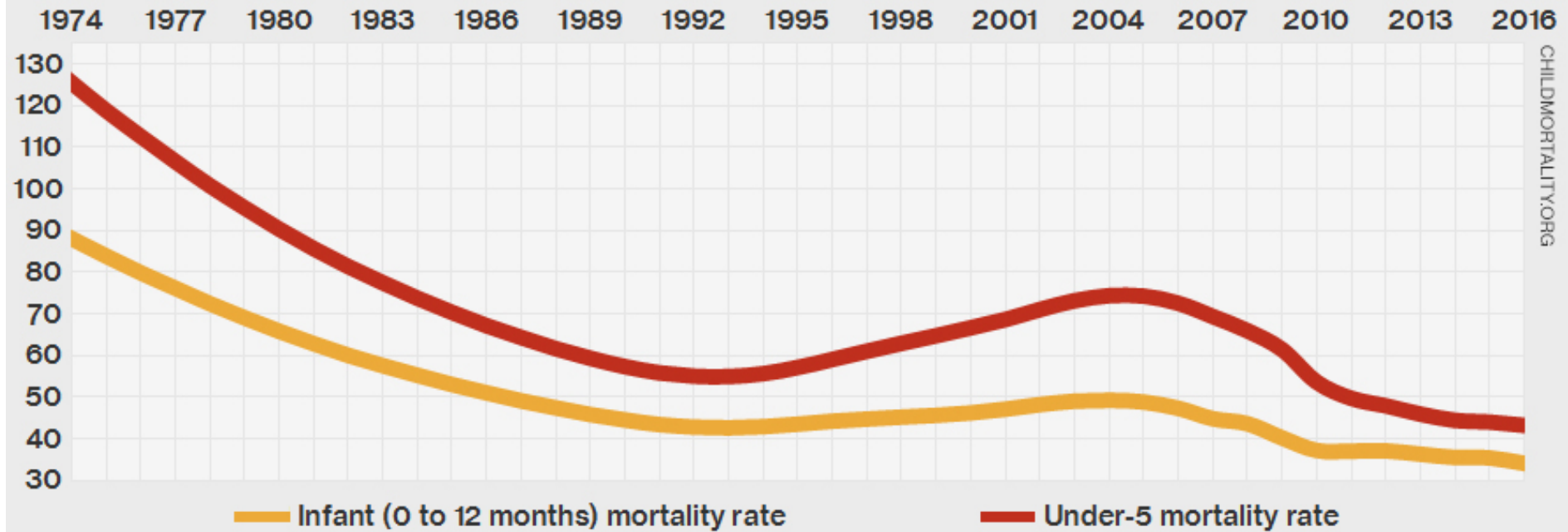


Death rates in Burkina Faso from 1993-2001 (Kynast-Wolf et al., 2005)



Child mortality from 1974 to 2016

Child mortality (number of deaths per 1,000 live births) in South Africa 1974 to 2016



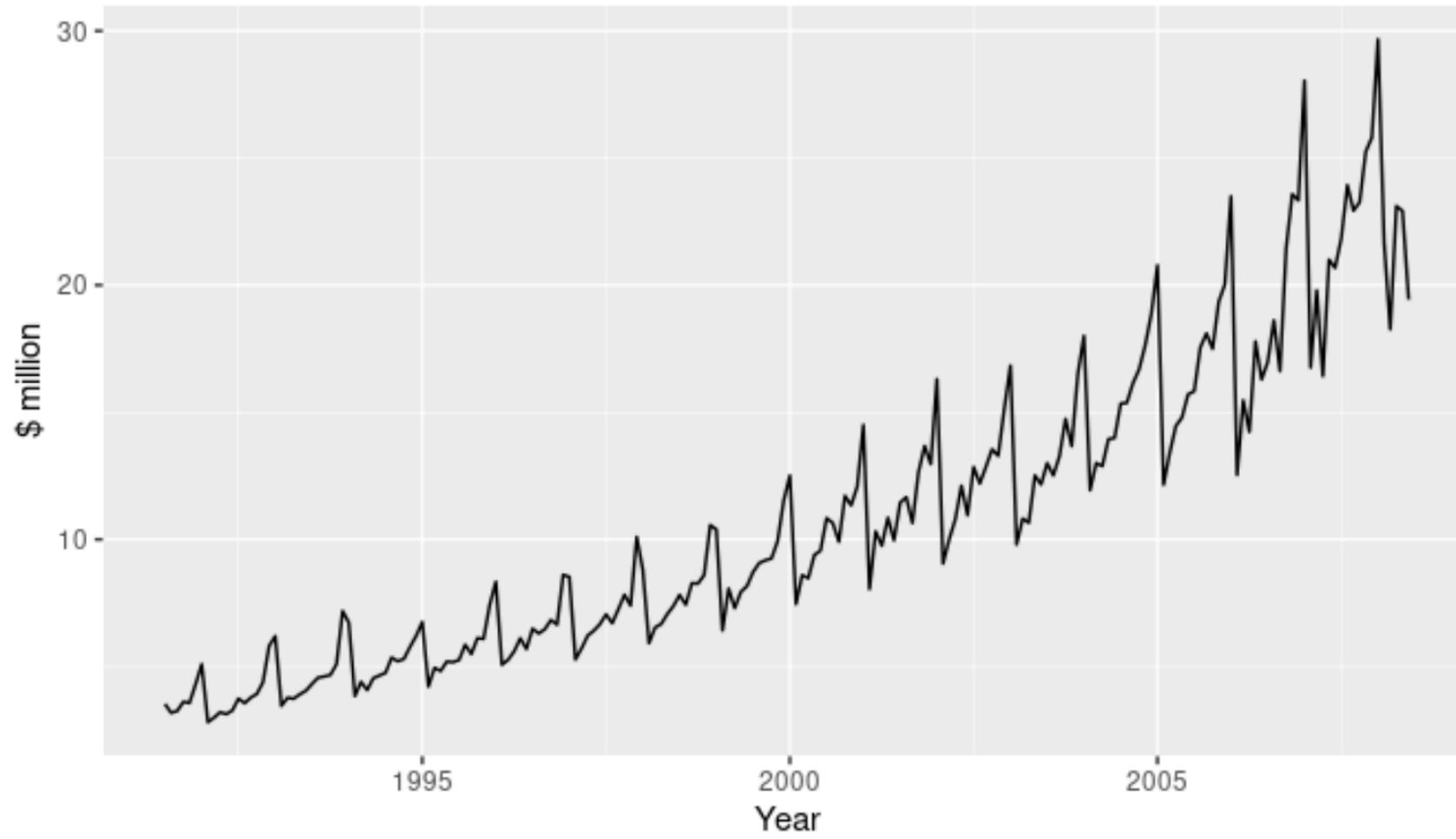
SouthAfrica-Gateway.com

GRAPHIC: MARY ALEXANDER • DATA: CHILDMORTALITY.ORG



GLOBAL HEALTH
RESEARCH CORE

Antidiabetic drug sales in Australia

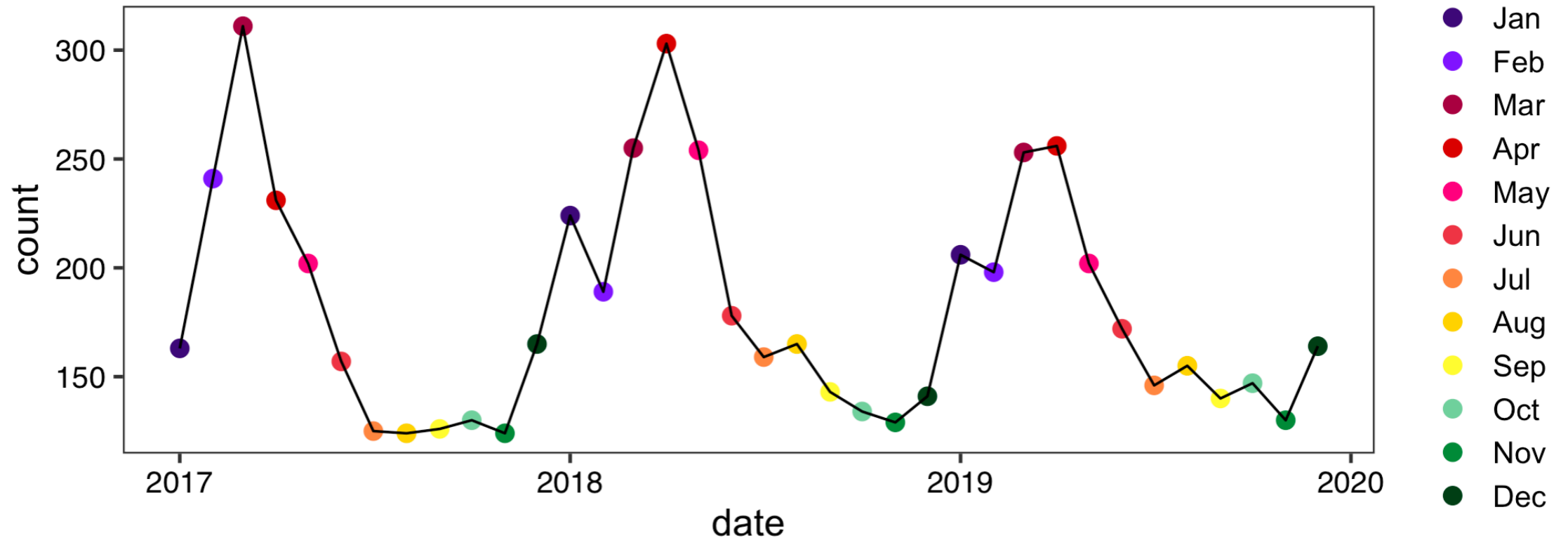


Source: *Forecasting: Principles and Practice* (<https://otexts.com/fpp2/>)



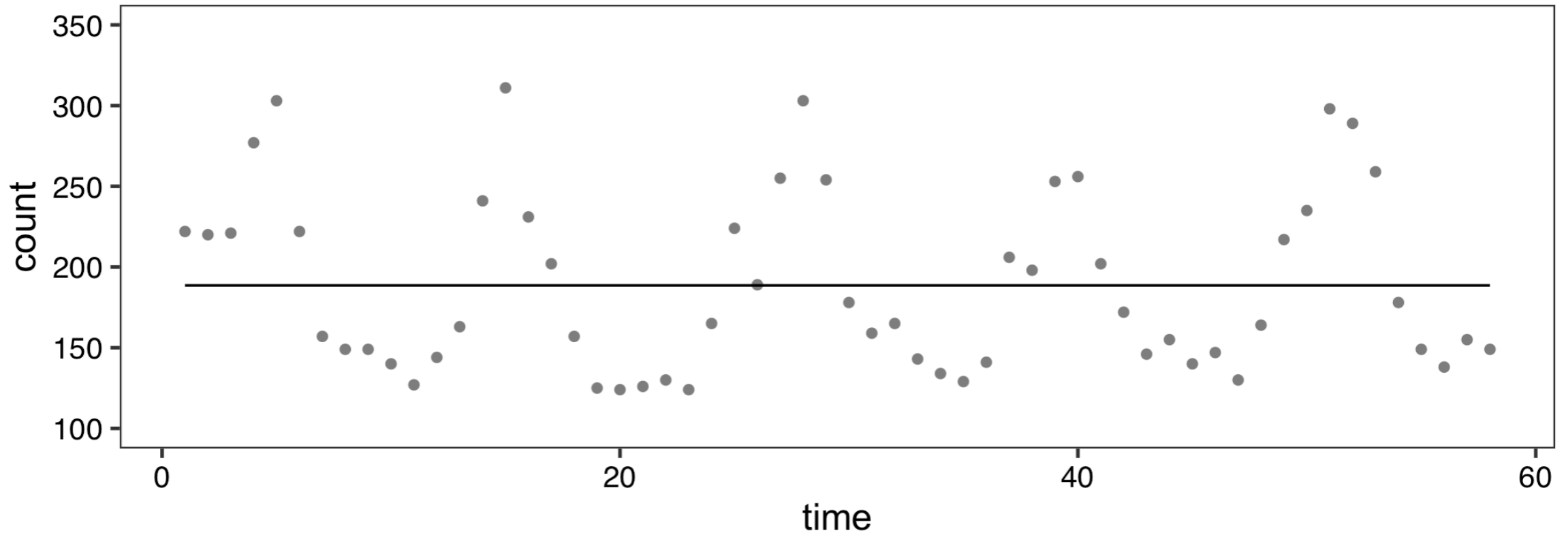
Activity: Malaria cases in Malawi facility

Please go to www.menti.com with 1576 1881



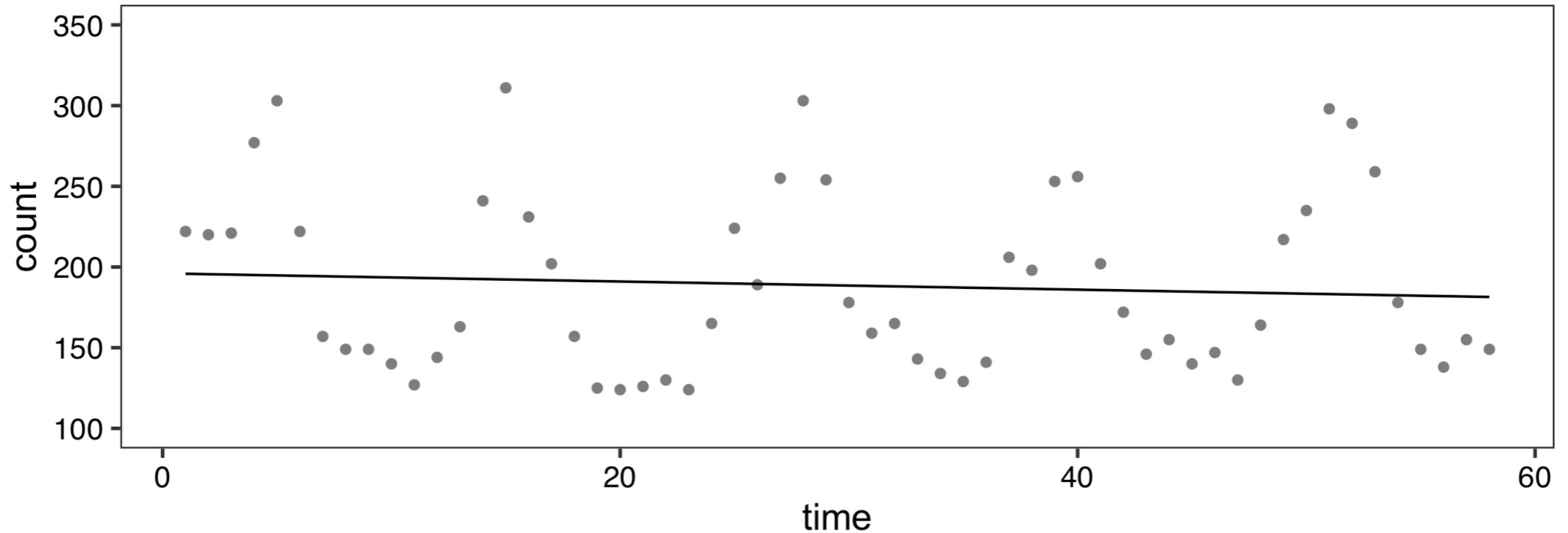
Malaria cases in Malawi facility

$$outcome_t = \beta_0 + \varepsilon_t$$



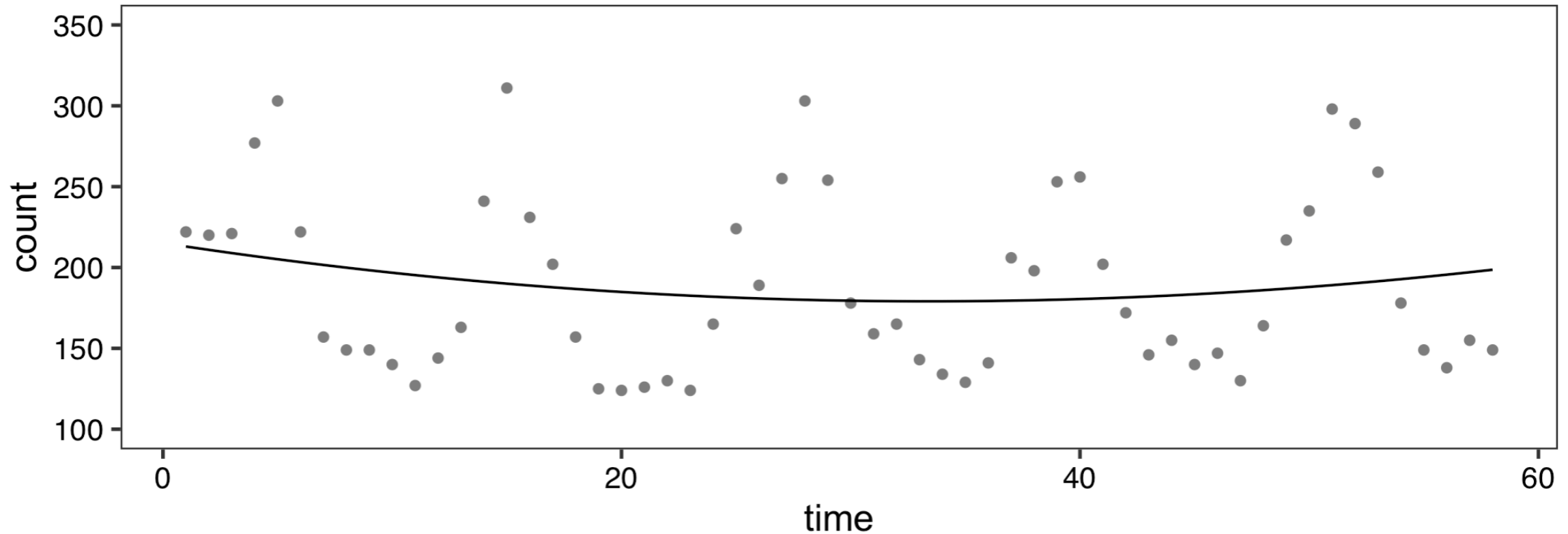
Malaria cases in Malawi facility

$$outcome_t = \beta_0 + \beta_1 \cdot time + \varepsilon_t$$



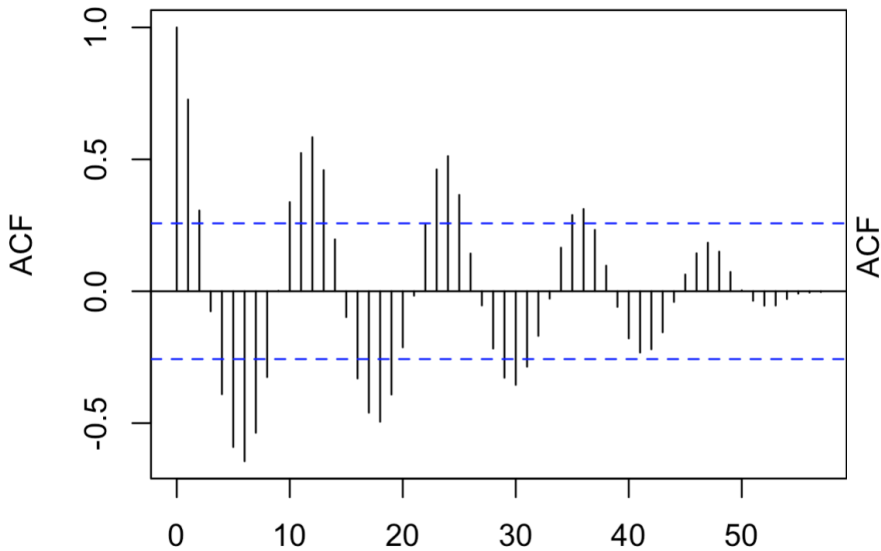
Malaria cases in Malawi facility

$$outcome_t = \beta_0 + \beta_1 \cdot time + \beta_2 \cdot time^2 + \varepsilon_t$$

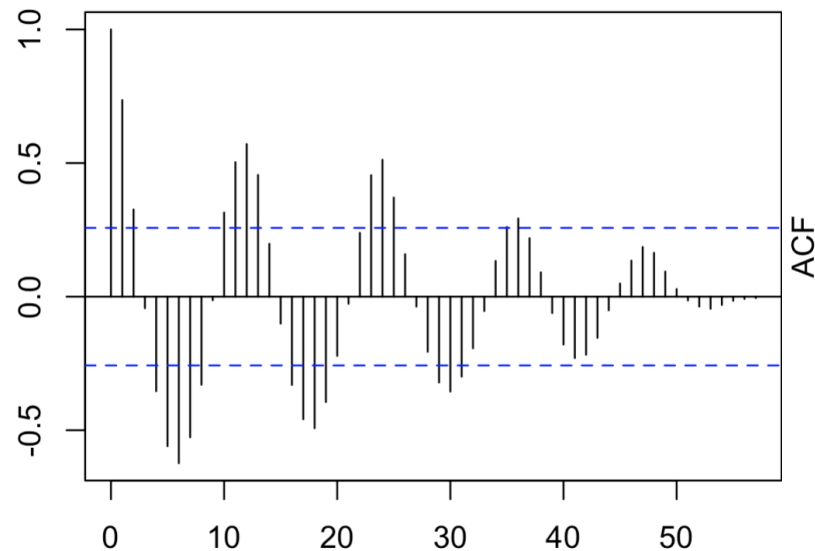


Model diagnostics: autocorrelation

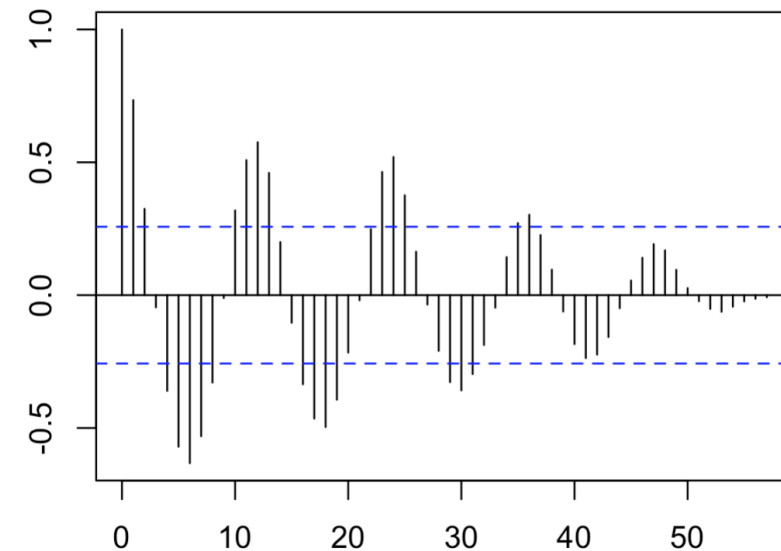
intercept only
model



intercept and slope
model



quadratic
model



**None of these models see any improvement over the other!
Need another method to capture “seasonality”!**

How to deal with seasonality and trend?

- **Seasonality:** Fourier series are popular ways to deal with seasonality in time series models (*other options: splines, dummy variables, etc.*)

$$x_{1,t} = \sin\left(\frac{2\pi t}{m}\right), x_{2,t} = \cos\left(\frac{2\pi t}{m}\right), x_{3,t} = \sin\left(\frac{4\pi t}{m}\right),$$
$$x_{4,t} = \cos\left(\frac{4\pi t}{m}\right), x_{5,t} = \sin\left(\frac{6\pi t}{m}\right), x_{6,t} = \cos\left(\frac{6\pi t}{m}\right),$$

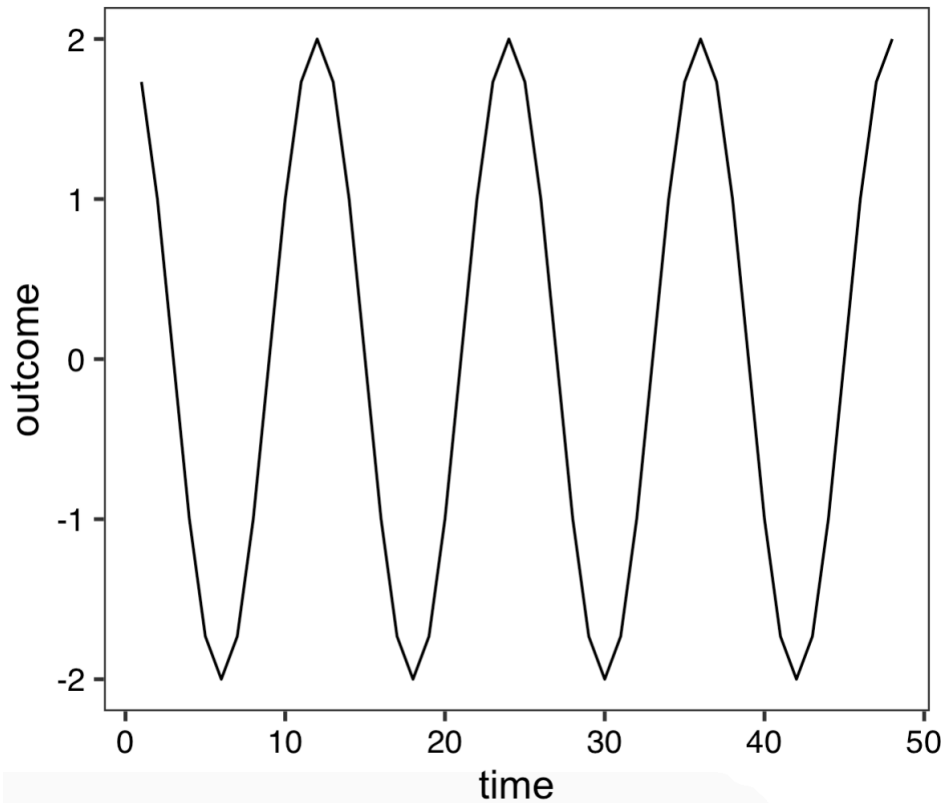
- **Trends:** Add a linear term(s) to capture yearly trend
 - Will only capture linear decreases or increases over time
 - If changes are not linear, dummy variables or more complex transformations (log, quadratic, etc.) can be used

Source: Forecasting: Principles and Practice (<https://otexts.com/fpp2/>)

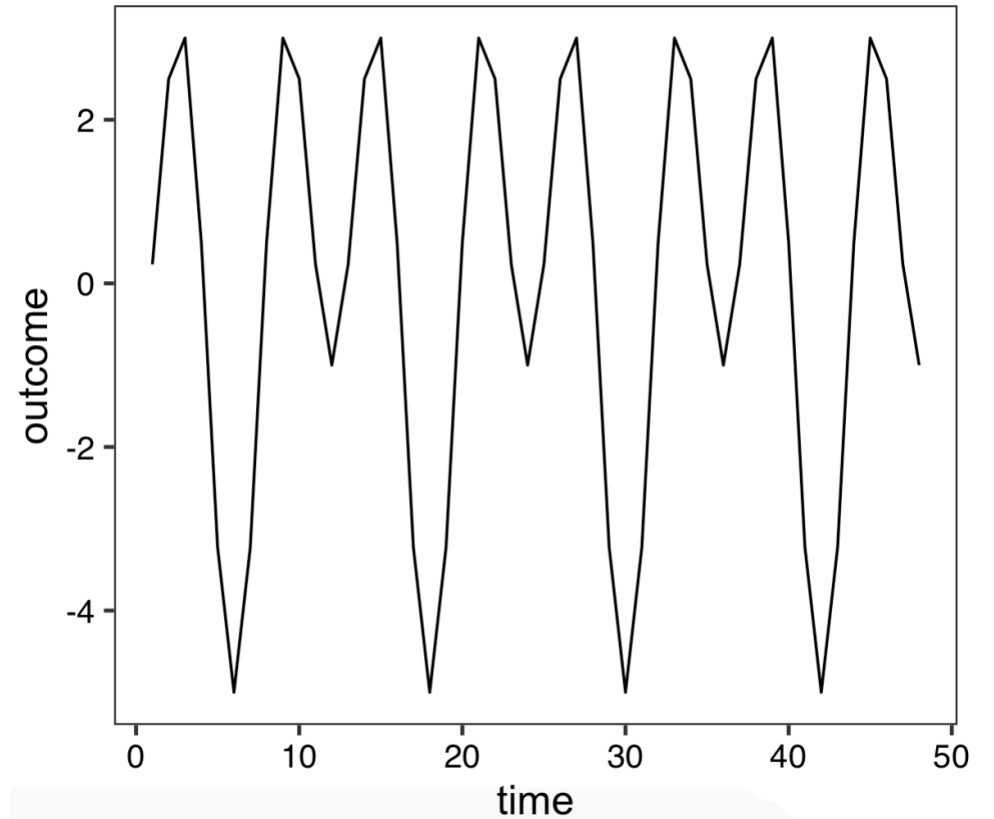


Fourier series (*examples*)

$$\sin(2\pi t/12) + \cos(2\pi t/12)$$

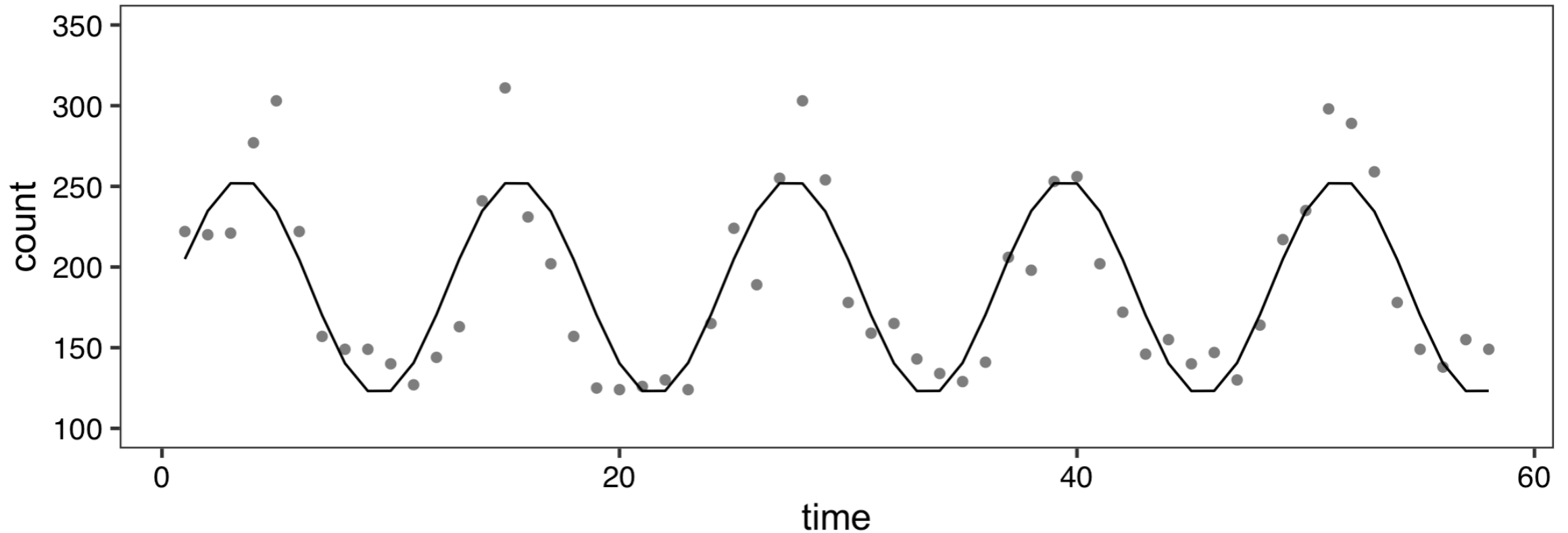


$$\sin(2\pi t/12) + \cos(2\pi t/12) + \sin(4\pi t/12) + \cos(4\pi t/12)$$

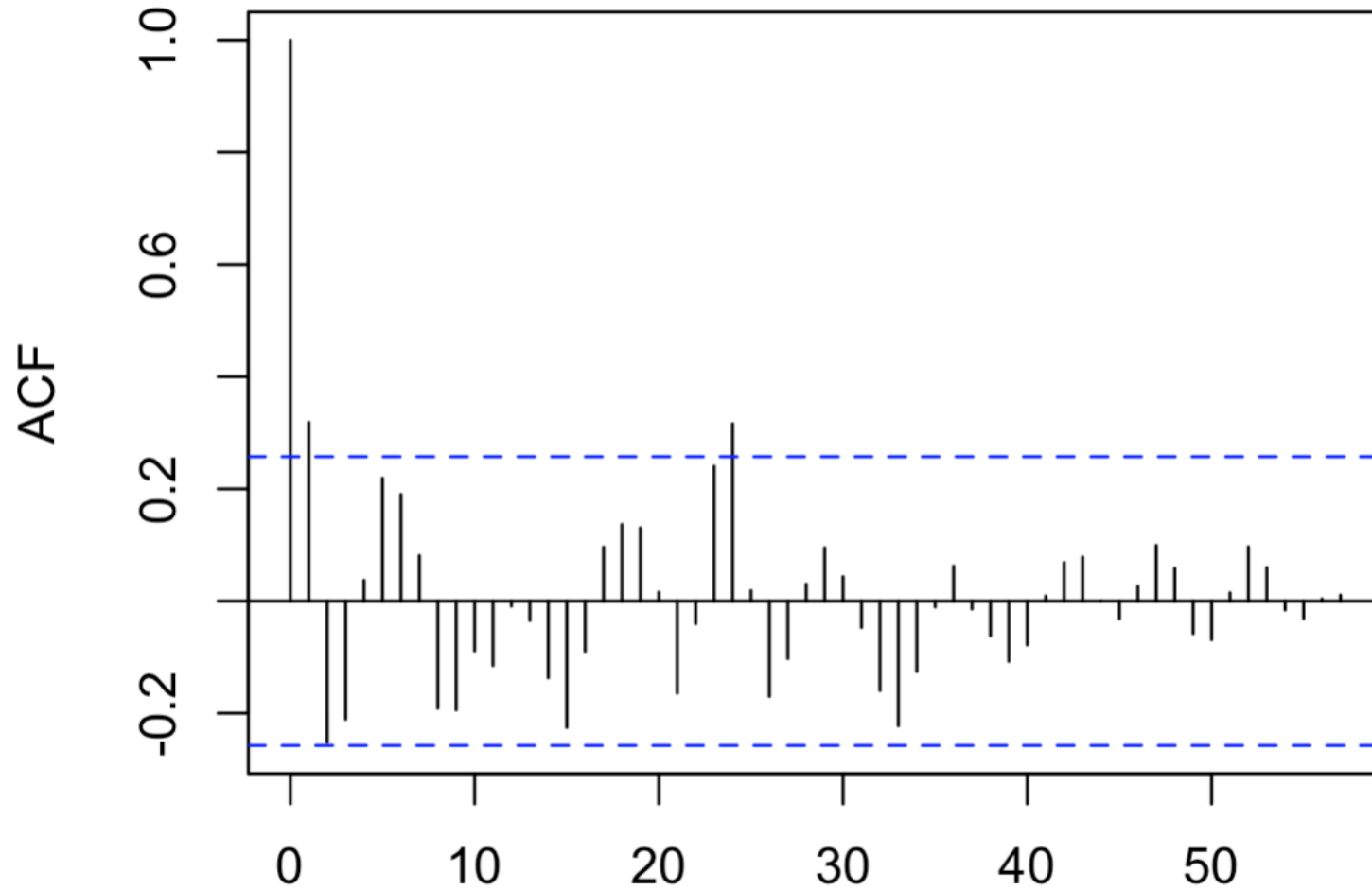


Malaria cases in Malawi facility

$$outcome_t = \beta_0 + \beta_1 \cdot \sin(2\pi t/12) + \beta_2 \cdot \cos(2\pi t/12) + \varepsilon_t$$



Model diagnostics: autocorrelation



Syndromic surveillance



Research questions with time series data

- **Describe** the behavior of an indicator over time
 - Is infant mortality decreasing over time? By how much?
 - What are the seasonal differences in malaria cases?
- **Detect** deviations from expected in an indicator
 - Is a region experiencing higher than expected cases of diarrhea?
 - Is the number of health facility deliveries lower than expected?
- **Measure** the impact of an intervention on an indicator
 - After social distancing measures were put in place, how many fewer COVID-19 cases were there?

Detecting deviations from expected

Syndromic surveillance: is the process of monitoring data on symptoms or outcomes related to a disease as a way to **detect** areas that might be affected by the disease.

Pros:

- Provide “warnings” for local areas.
- Uses existing data.
- Process can be automated.

Cons:

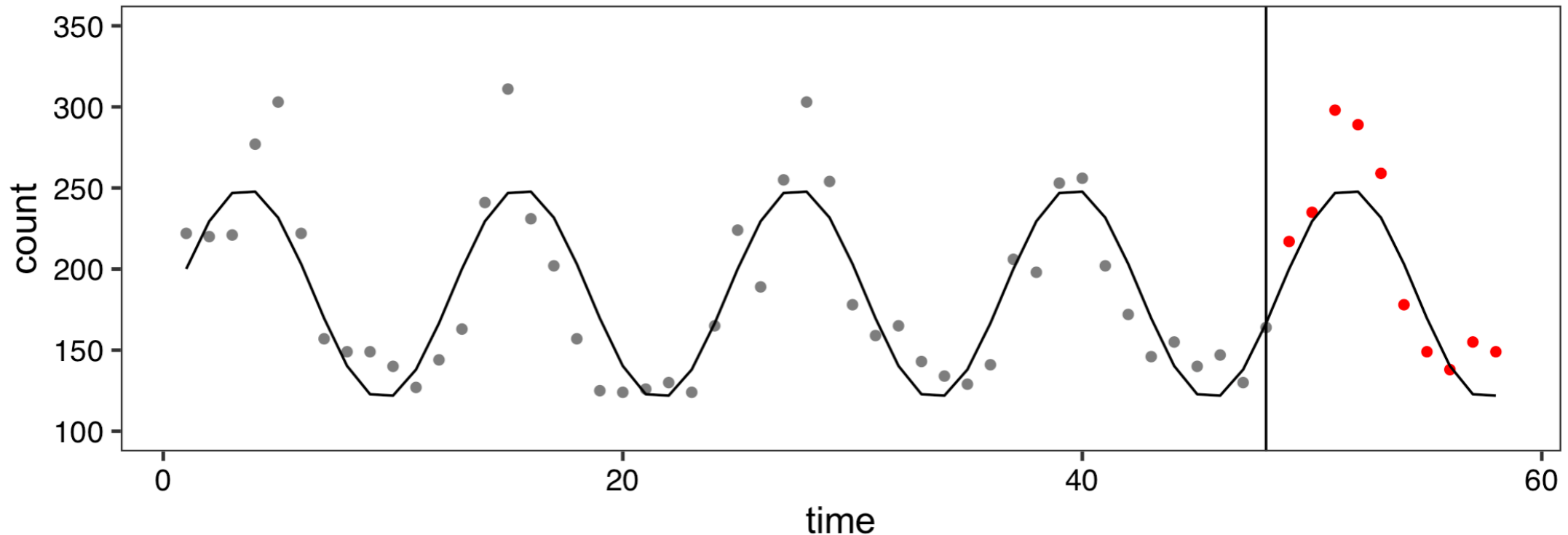
- Not as good as monitoring the disease directly.
- Changes could be explained by **other factors** that should be considered.



How to conduct syndromic surveillance

- **Step 1.** Choose relevant indicators to follow over time (*Session 1*) and format data for analysis (*Session 4*)
- **Step 2.** Determine baseline and evaluation periods
- **Step 3.** Fit time series model to baseline period (*Sessions 2 & 3*)
- **Step 4.** Using the model from Step 3, calculate deviations from expected in the evaluation period (*Session 3*)
- **Step 5.** Produce interpretable visualizations (*Session 5*)

Group activity: *how should we calculate deviations from expected?*



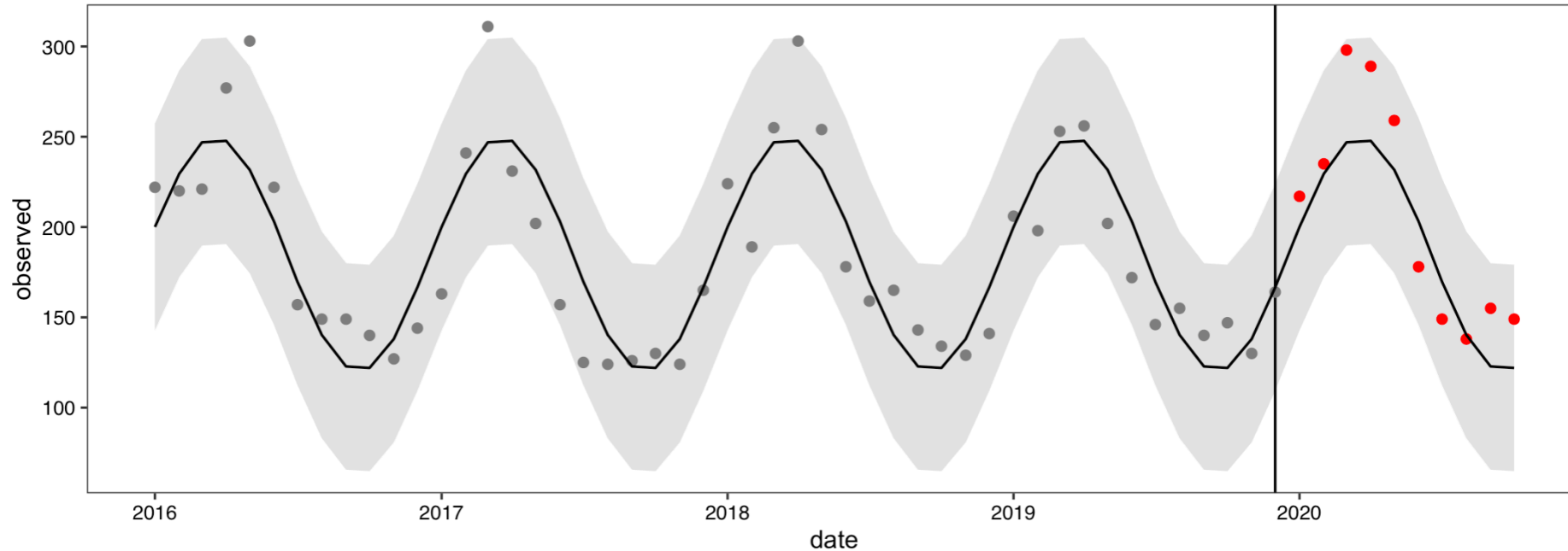
Group activity: *how should we calculate deviations from expected?*

1. Are the number of malaria cases higher or lower than expected in January 2020? By how many malaria cases?
2. In the evaluation period, are the observed numbers of malaria cases systematically higher than expected, lower than expected, or is there no discernable pattern?
3. Does using *predicted cases - observed cases* to identify deviations make sense? How could this measure be improved?

Your group should answer these questions on a Google Form in a Breakout Room.



Prediction intervals



Prediction interval: the range of values where a future individual observation (monthly count) is likely to fall.

Prediction intervals are different than confidence intervals, because they correspond to an individual value, not the mean.

Lab activity: Syndromic Surveillance of Acute Respiratory Infection Cases at Liberia facility

- Lab will be taught by Don today

Next lecture: Cleaning the Data

- Extracting data
- Setting up data in usable format
- Identifying outliers
- Dealing with missing data
- Automation