MONASH University

MONASH BUSINESS SCHOOL

A feast of time series tools

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Outline

Outline

Tidyverts packages

tidyverts.org

Overview

Feature Extraction And Statistics for Time Series

- works with tidy temporal data provided by the tsibble package.
- produces time series features, decompositions, statistical summaries and visualisations.

Outline

tsibble objects

```
global_economy
```

```
## # A tsibble: 15,150 x 6 [1Y]
## # Key:       Country [263]
##     Year Country              GDP Imports Exports Population
##    <dbl> <fct>                <dbl>   <dbl>   <dbl>      <dbl>
##  1  1960 Afghanistan  537777811.    7.02    4.13    8996351
##  2  1961 Afghanistan  548888896.    8.10    4.45    9166764
##  3  1962 Afghanistan  546666678.    9.35    4.88    9345868
##  4  1963 Afghanistan  751111191.   16.9     9.17    9533954
##  5  1964 Afghanistan  800000044.   18.1     8.89    9731361
##  6  1965 Afghanistan 1006666638.   21.4    11.3     9938414
##  7  1966 Afghanistan 1399999967.   18.6     8.57   10152331
##  8  1967 Afghanistan 1673333418.   14.2     6.77   10372630
##  9  1968 Afghanistan 1373333367.   15.2     8.90   10604346
## 10  1969 Afghanistan 1408888922.   15.0    10.1    10854428
## # ... with 15,140 more rows
```

tsibble objects

```
global_economy
```

```
## # A tsibble: 15,150 x 6 [1Y]
## # Key:       Country [263]
##     Year Country              GDP Imports Exports Population
##    Index <fct>                <dbl>   <dbl>   <dbl>      <dbl>
##  1  1960 Afghanistan  537777811.    7.02    4.13    8996351
##  2  1961 Afghanistan  548888896.    8.10    4.45    9166764
##  3  1962 Afghanistan  546666678.    9.35    4.88    9345868
##  4  1963 Afghanistan  751111191.   16.9     9.17    9533954
##  5  1964 Afghanistan  800000044.   18.1     8.89    9731361
##  6  1965 Afghanistan 1006666638.   21.4    11.3     9938414
##  7  1966 Afghanistan 1399999967.   18.6     8.57   10152331
##  8  1967 Afghanistan 1673333418.   14.2     6.77   10372630
##  9  1968 Afghanistan 1373333367.   15.2     8.90   10604346
## 10  1969 Afghanistan 1408888922.   15.0    10.1    10854428
## # ... with 15,140 more rows
```

tsibble objects

```
global_economy
```

```
## # A tsibble: 15,150 x 6 [1Y]
## # Key:       Country [263]
##     Year Country              GDP Imports Exports Population
##    Index Key                <dbl>   <dbl>   <dbl>      <dbl>
##  1  1960 Afghanistan  537777811.    7.02    4.13    8996351
##  2  1961 Afghanistan  548888896.    8.10    4.45    9166764
##  3  1962 Afghanistan  546666678.    9.35    4.88    9345868
##  4  1963 Afghanistan  751111191.   16.9     9.17    9533954
##  5  1964 Afghanistan  800000044.   18.1     8.89    9731361
##  6  1965 Afghanistan 1006666638.   21.4    11.3     9938414
##  7  1966 Afghanistan 1399999967.   18.6     8.57   10152331
##  8  1967 Afghanistan 1673333418.   14.2     6.77   10372630
##  9  1968 Afghanistan 1373333367.   15.2     8.90   10604346
## 10  1969 Afghanistan 1408888922.   15.0    10.1    10854428
## # ... with 15,140 more rows
```

tsibble objects

```
global_economy
```

```
## # A tsibble: 15,150 x 6 [1Y]
## # Key:       Country [263]
##     Year Country              GDP Imports Exports Population
##    Index Key                Measured variables
##  1  1960 Afghanistan  537777811.    7.02    4.13    8996351
##  2  1961 Afghanistan  548888896.    8.10    4.45    9166764
##  3  1962 Afghanistan  546666678.    9.35    4.88    9345868
##  4  1963 Afghanistan  751111191.   16.9     9.17    9533954
##  5  1964 Afghanistan  800000044.   18.1     8.89    9731361
##  6  1965 Afghanistan 1006666638.   21.4    11.3     9938414
##  7  1966 Afghanistan 1399999967.   18.6     8.57   10152331
##  8  1967 Afghanistan 1673333418.   14.2     6.77   10372630
##  9  1968 Afghanistan 1373333367.   15.2     8.90   10604346
## 10  1969 Afghanistan 1408888922.   15.0    10.1    10854428
## # ... with 15,140 more rows
```

tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:       Region, State, Purpose [304]
##    Quarter Region   State Purpose  Trips
##      <qtr> <chr>    <chr> <chr>    <dbl>
##  1 1998 Q1 Adelaide SA    Business  135.
##  2 1998 Q2 Adelaide SA    Business  110.
##  3 1998 Q3 Adelaide SA    Business  166.
##  4 1998 Q4 Adelaide SA    Business  127.
##  5 1999 Q1 Adelaide SA    Business  137.
##  6 1999 Q2 Adelaide SA    Business  200.
##  7 1999 Q3 Adelaide SA    Business  169.
##  8 1999 Q4 Adelaide SA    Business  134.
##  9 2000 Q1 Adelaide SA    Business  154.
## 10 2000 Q2 Adelaide SA    Business  169.
## # ... with 24,310 more rows
```

tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:       Region, State, Purpose [304]
##    Quarter Region   State Purpose  Trips
##      Index <chr>    <chr> <chr>    <dbl>
##  1 1998 Q1 Adelaide SA    Business  135.
##  2 1998 Q2 Adelaide SA    Business  110.
##  3 1998 Q3 Adelaide SA    Business  166.
##  4 1998 Q4 Adelaide SA    Business  127.
##  5 1999 Q1 Adelaide SA    Business  137.
##  6 1999 Q2 Adelaide SA    Business  200.
##  7 1999 Q3 Adelaide SA    Business  169.
##  8 1999 Q4 Adelaide SA    Business  134.
##  9 2000 Q1 Adelaide SA    Business  154.
## 10 2000 Q2 Adelaide SA    Business  169.
## # ... with 24,310 more rows
```

tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:       Region, State, Purpose [304]
##    Quarter Region   State Purpose  Trips
##      Index    Keys                <dbl>
##  1 1998 Q1 Adelaide SA    Business  135.
##  2 1998 Q2 Adelaide SA    Business  110.
##  3 1998 Q3 Adelaide SA    Business  166.
##  4 1998 Q4 Adelaide SA    Business  127.
##  5 1999 Q1 Adelaide SA    Business  137.
##  6 1999 Q2 Adelaide SA    Business  200.
##  7 1999 Q3 Adelaide SA    Business  169.
##  8 1999 Q4 Adelaide SA    Business  134.
##  9 2000 Q1 Adelaide SA    Business  154.
## 10 2000 Q2 Adelaide SA    Business  169.
## # ... with 24,310 more rows
```

tsibble objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:       Region, State, Purpose [304]
##    Quarter Region   State Purpose  Trips
##      Index    Keys                Measure
##  1 1998 Q1 Adelaide SA    Business  135.
##  2 1998 Q2 Adelaide SA    Business  110.
##  3 1998 Q3 Adelaide SA    Business  166.
##  4 1998 Q4 Adelaide SA    Business  127.
##  5 1999 Q1 Adelaide SA    Business  137.
##  6 1999 Q2 Adelaide SA    Business  200.
##  7 1999 Q3 Adelaide SA    Business  169.
##  8 1999 Q4 Adelaide SA    Business  134.
##  9 2000 Q1 Adelaide SA    Business  154.
## 10 2000 Q2 Adelaide SA    Business  169.
## # ... with 24,310 more rows
```

`tsibble` objects

```
tourism
```

```
## # A tsibble: 24,320 x 5 [1Q]
## # Key:       Region, State, Purpose [304]
##    Quarter Region   State Purpose  Trips
##      Index    Keys                Measure
##  1 1998 Q1 Adelaide SA    Business  135.
##  2 1998 Q2 Adelaide SA    Business  110.
##  3 1998 Q3 Adelaide SA    Business  166.
##  4 1998 Q4 Adelaide SA    Business  127.
##  5 1999 Q1 Adelaide SA    Business  137.
##  6 1999 Q2 Adelaide SA    Business  200.
##  7 1999 Q3 Adelaide SA    Business  169.
##  8 1999 Q4 Adelaide SA    Business  134.
##  9 2000 Q1 Adelaide SA    Business  154.
## 10 2000 Q2 Adelaide SA    Business  169.
## # ... with 24,310 more rows
```

Domestic visitor nights in thousands by state/region and purpose.

Holidays by state

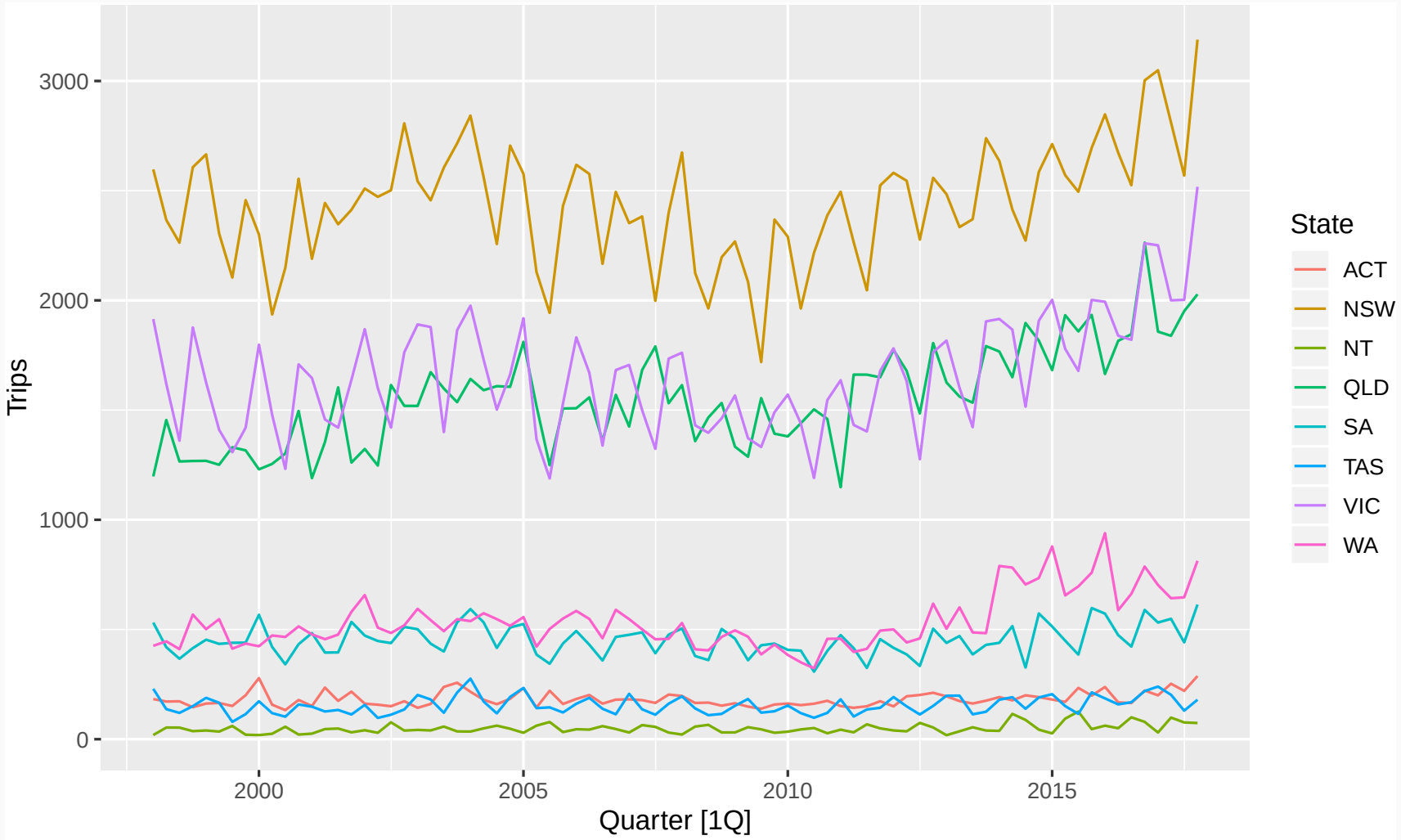
```
holidays <- tourism %>%
  filter(Purpose=="Holiday") %>%
  group_by(State) %>%
  summarise(Trips = sum(Trips))
```

```
## # A tsibble: 640 x 3 [1Q]
## # Key:       State [8]
##    Quarter State Trips
##      <qtr> <chr> <dbl>
##  1 1998 Q1 ACT    183.
##  2 1998 Q2 ACT    172.
##  3 1998 Q3 ACT    173.
##  4 1998 Q4 ACT    146.
##  5 1999 Q1 ACT    162.
##  6 1999 Q2 ACT    165.
##  7 1999 Q3 ACT    151.
##  8 1999 Q4 ACT    200.
##  9 2000 Q1 ACT    279.
## 10 2000 Q2 ACT    157.
```

Outline

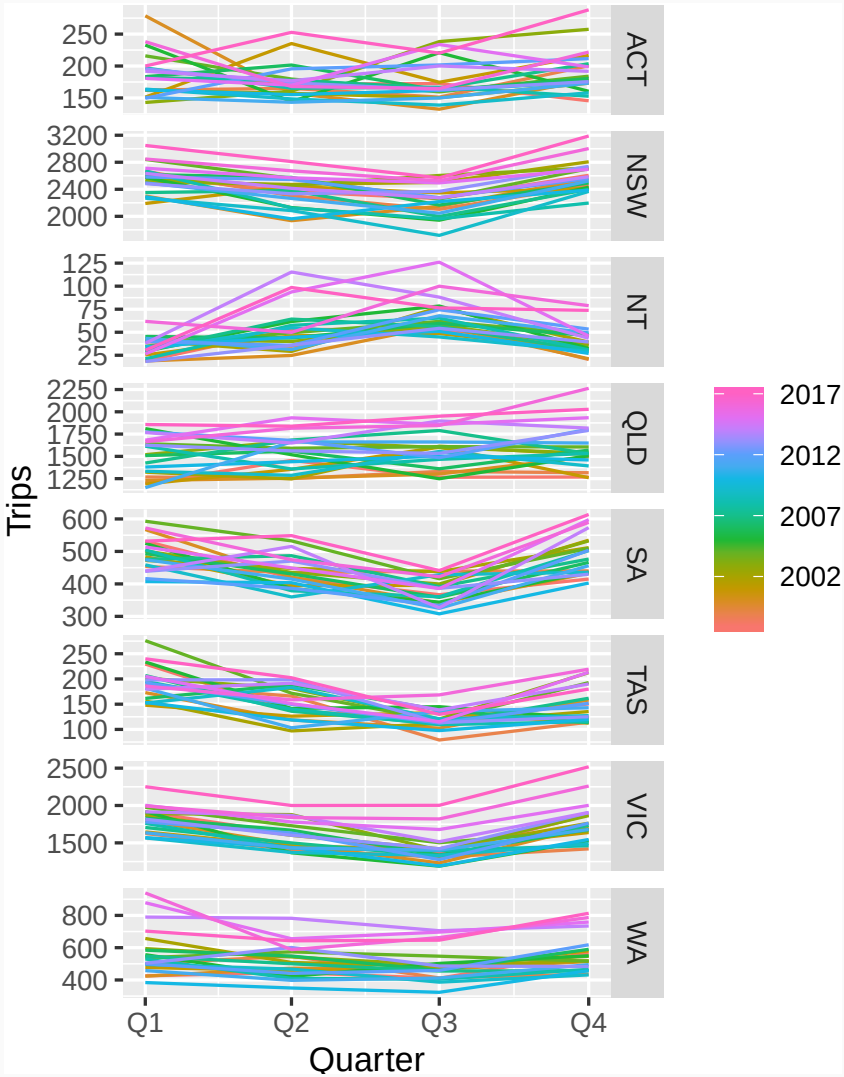
Time plots

```
holidays %>% autoplot(Trips)
```



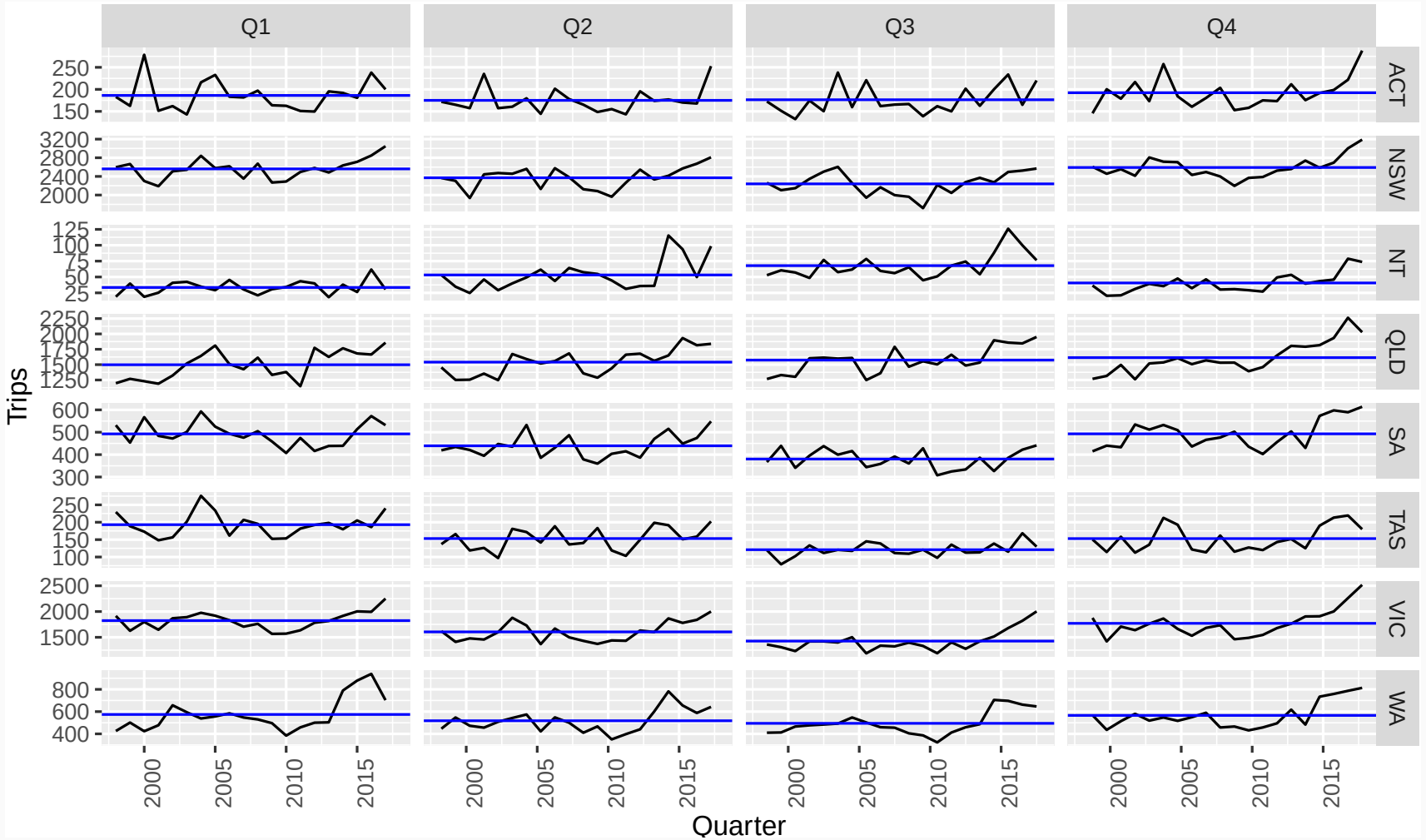
Season plots

```
holidays %>% gg_season(Trips)
```



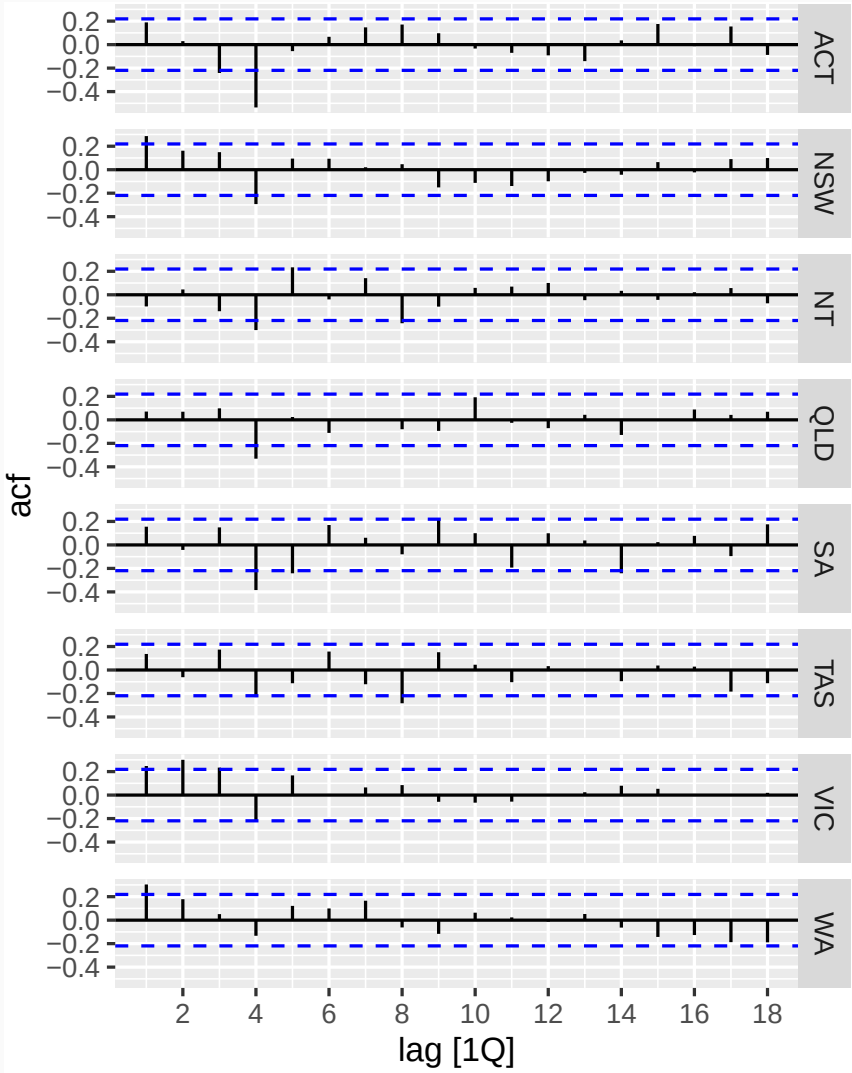
Graphics

```
holidays %>% gg_subseries(Trips)
```



Graphics

```
holidays %>% ACF(difference(Trips, 4)) %>% autoplot()
```



Outline

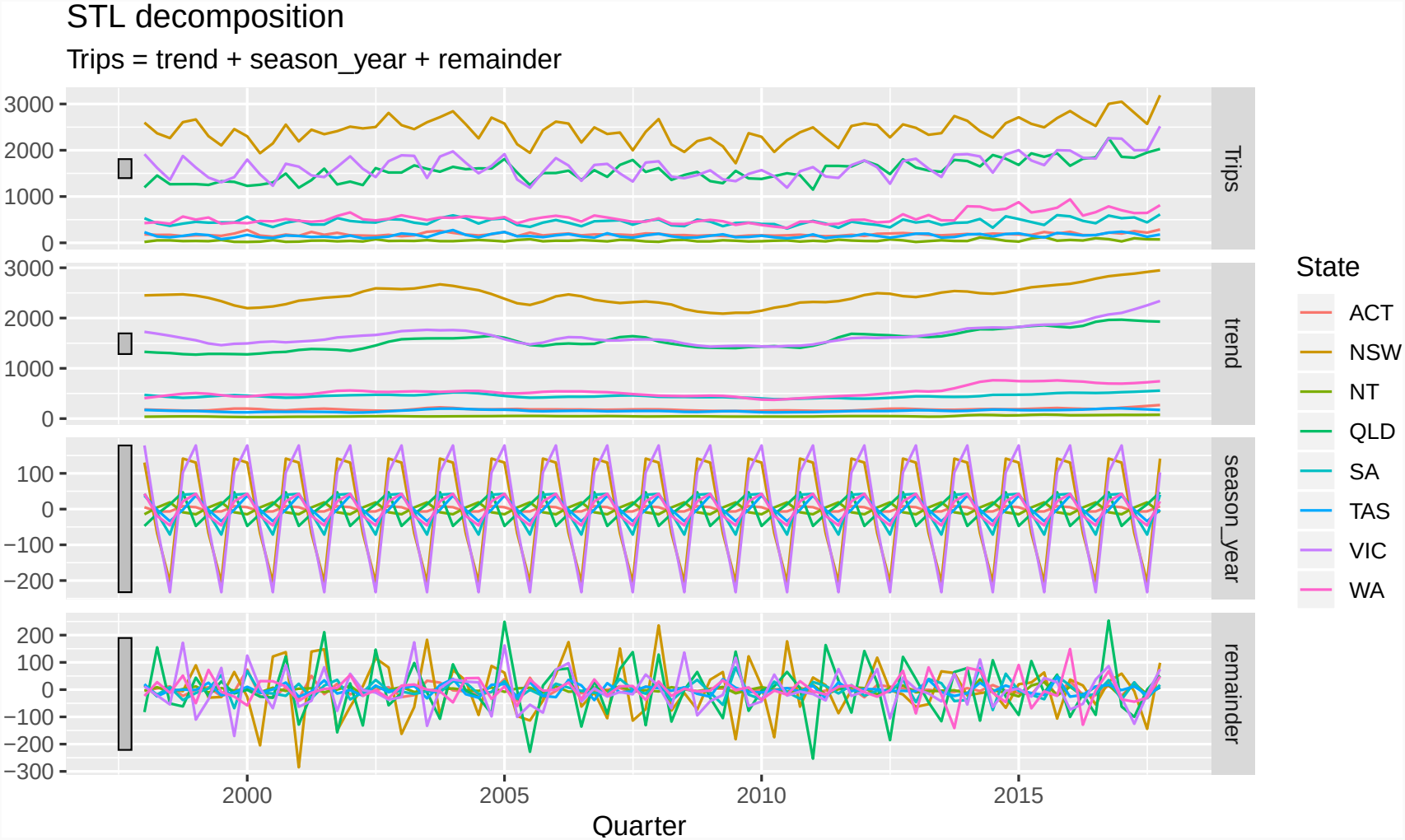
Decompositions

The feasts package supports four common time series decomposition methods:

- Classical decomposition
- STL decomposition
- X11 decomposition
- X-13ARIMA-SEATS decomposition

Decompositions

```
holidays %>% STL(Trips ~ season(window = "periodic")) %>%
  autoplot()
```



Outline

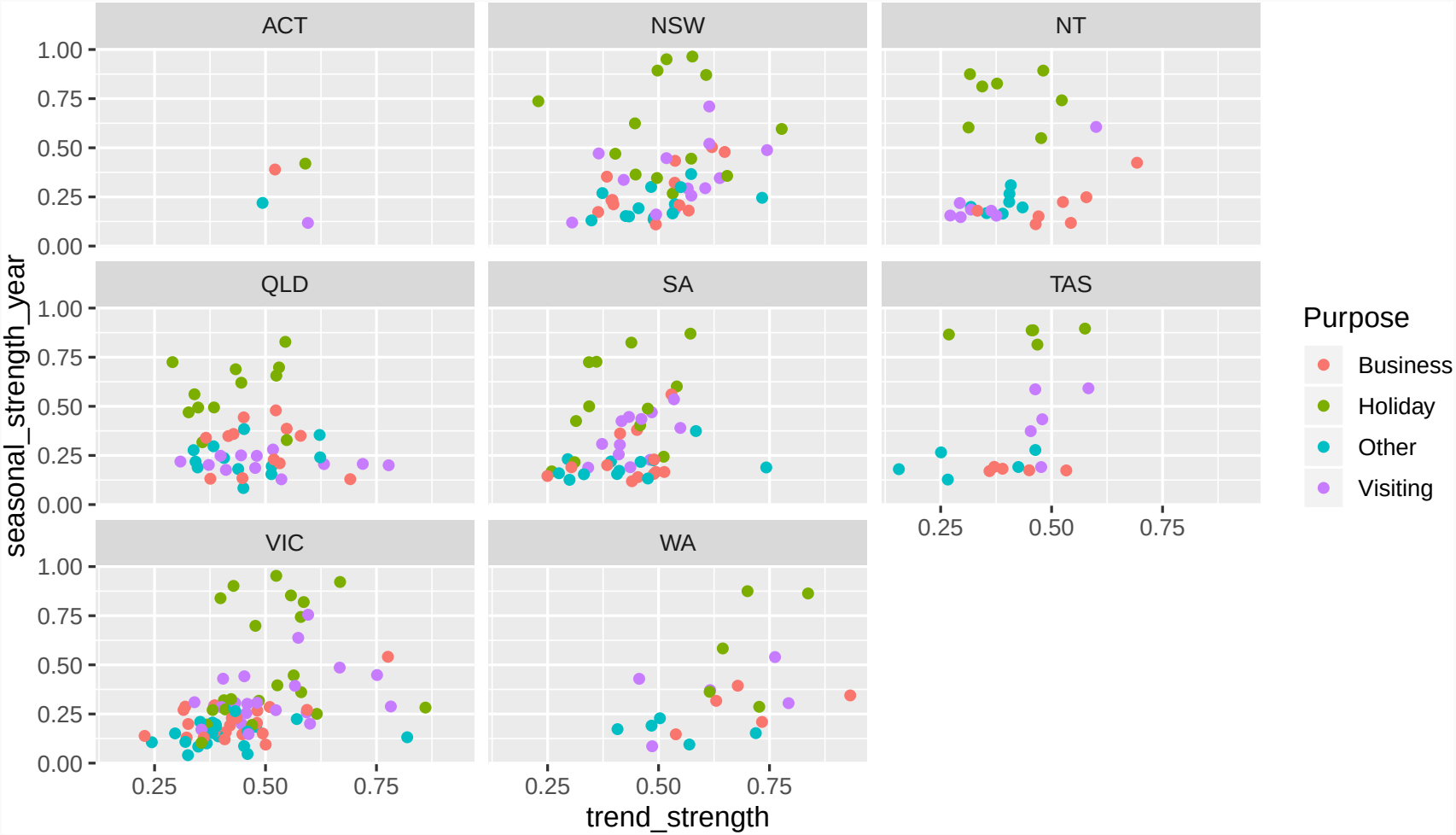
Feature extraction and statistics

```
tourism %>% features(Trips, feature_set(tags="stl"))
```

```
## # A tibble: 304 x 10
##    Region State Purpose trend_strength seasonal_streng~
##    <chr>  <chr> <chr>            <dbl>            <dbl>
##  1 Adela~ SA    Busine~          0.451            0.380
##  2 Adela~ SA    Holiday          0.541            0.601
##  3 Adela~ SA    Other            0.743            0.189
##  4 Adela~ SA    Visiti~          0.433            0.446
##  5 Adela~ SA    Busine~          0.453            0.140
##  6 Adela~ SA    Holiday          0.512            0.244
##  7 Adela~ SA    Other            0.584            0.374
##  8 Adela~ SA    Visiti~          0.481            0.228
##  9 Alice~ NT    Busine~          0.526            0.224
## 10 Alice~ NT    Holiday          0.377            0.827
## # ... with 294 more rows, and 5 more variables:
## #   spikiness <dbl>, linearity <dbl>, curvature <dbl>,
## #   seasonal_peak_year <dbl>, seasonal_trough_year <dbl>
```

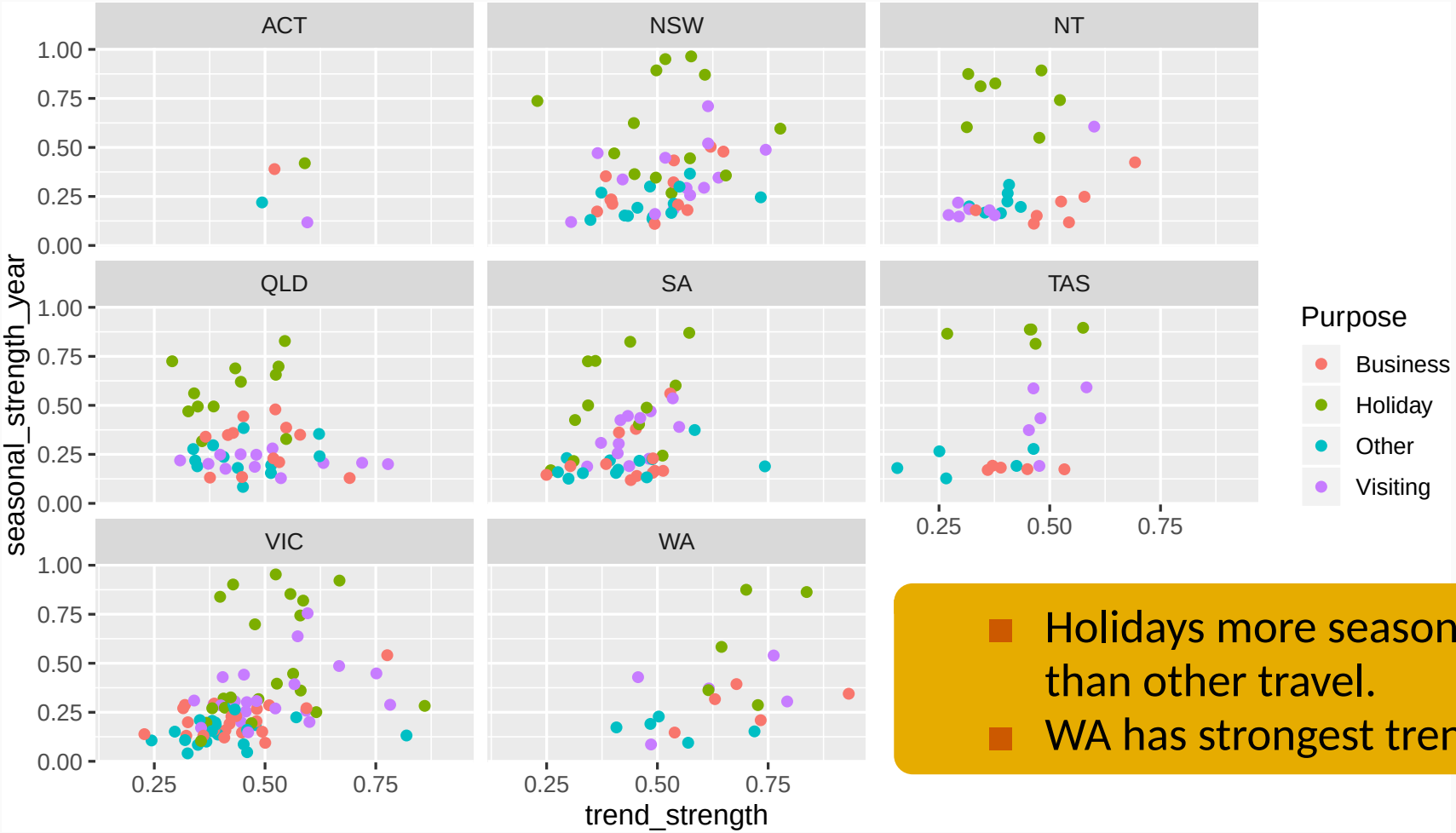
Feature extraction and statistics

```
tourism %>% features(Trips, feature_set(tags="stl")) %>%
ggplot(aes(x=trend_strength, y=seasonal_strength_year, col=Purpose)) +
  geom_point() + facet_wrap(vars(State))
```



Feature extraction and statistics

```
tourism %>% features(Trips, feature_set(tags="stl")) %>%
ggplot(aes(x=trend_strength, y=seasonal_strength_year, col=Purpose)) +
  geom_point() + facet_wrap(vars(State))
```



- Holidays more seasonal than other travel.
- WA has strongest trends.

Feature extraction and statistics

Find the most seasonal time series:

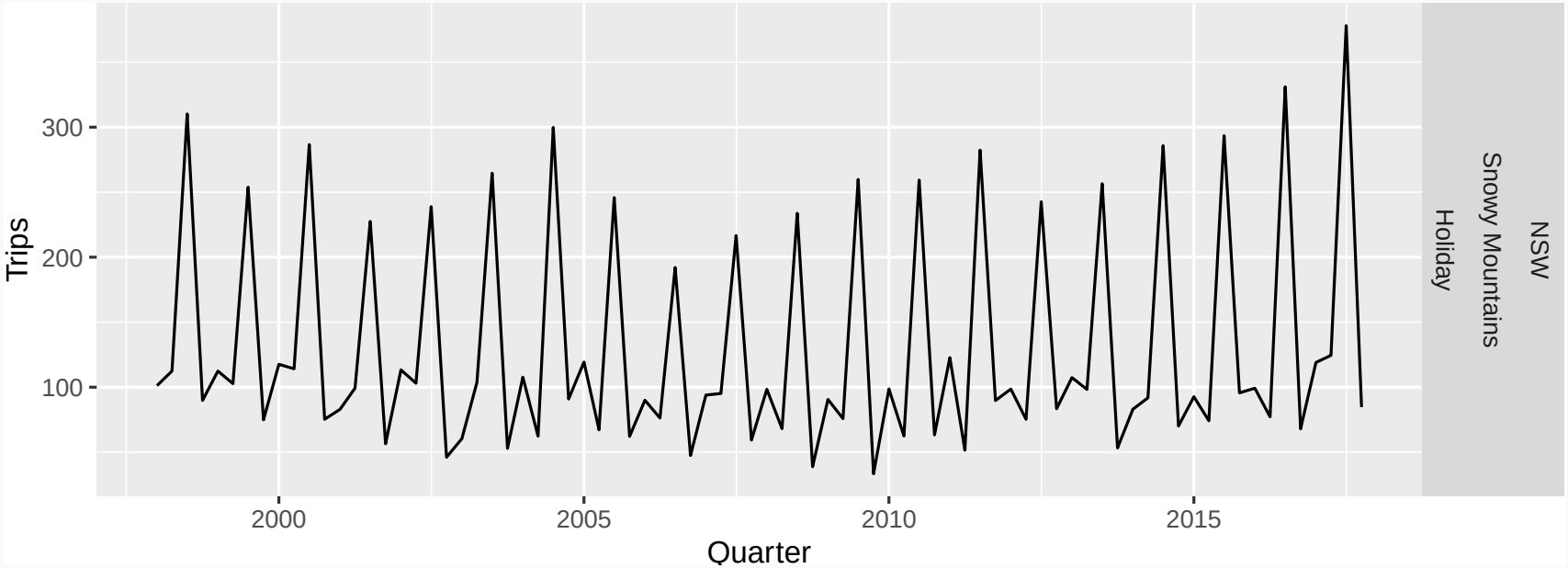
```
most_seasonal <- tourism %>%
  features(Trips, feature_set(tags="stl")) %>%
  filter(seasonal_strength_year == max(seasonal_strength_year))
```

Feature extraction and statistics

Find the most seasonal time series:

```
most_seasonal <- tourism %>%
  features(Trips, feature_set(tags="stl")) %>%
  filter(seasonal_strength_year == max(seasonal_strength_year))
```

```
tourism %>%
  right_join(most_seasonal, by = c("State","Region","Purpose")) %>%
  ggplot(aes(x = Quarter, y = Trips)) + geom_line() +
  facet_grid(vars(State,Region,Purpose))
```



Feature extraction and statistics

```
tourism_features <- tourism %>%
  features(Trips, feature_set(pkgs="feasts"))
```

All features from the feasts package

```
## # A tibble: 304 x 45
##    Region State Purpose trend_strength seasonal_streng~
##    <chr>  <chr> <chr>             <dbl>            <dbl>
##  1 Adela~ SA    Busine~           0.451            0.380
##  2 Adela~ SA    Holiday           0.541            0.601
##  3 Adela~ SA    Other             0.743            0.189
##  4 Adela~ SA    Visiti~           0.433            0.446
##  5 Adela~ SA    Busine~           0.453            0.140
##  6 Adela~ SA    Holiday           0.512            0.244
##  7 Adela~ SA    Other             0.584            0.374
##  8 Adela~ SA    Visiti~           0.481            0.228
##  9 Alice~ NT    Busine~           0.526            0.224
## 10 Alice~ NT    Holiday           0.377            0.827
## # ... with 294 more rows, and 40 more variables:
## #   spikiness <dbl>, linearity <dbl>, curvature <dbl>,
## #   seasonal_peak_year <dbl>, seasonal_trough_year <dbl>,
## #   acf1 <dbl>, acf10 <dbl>, diff1_acf1 <dbl>,
## #   diff1_acf10 <dbl>, diff2_acf1 <dbl>, diff2_acf10 <dbl>,
```

Feature extraction and statistics

```
pcs <- tourism_features %>% select(-State, -Region, -Purpose) %>%
  prcomp(scale=TRUE) %>% augment(tourism_features)
```

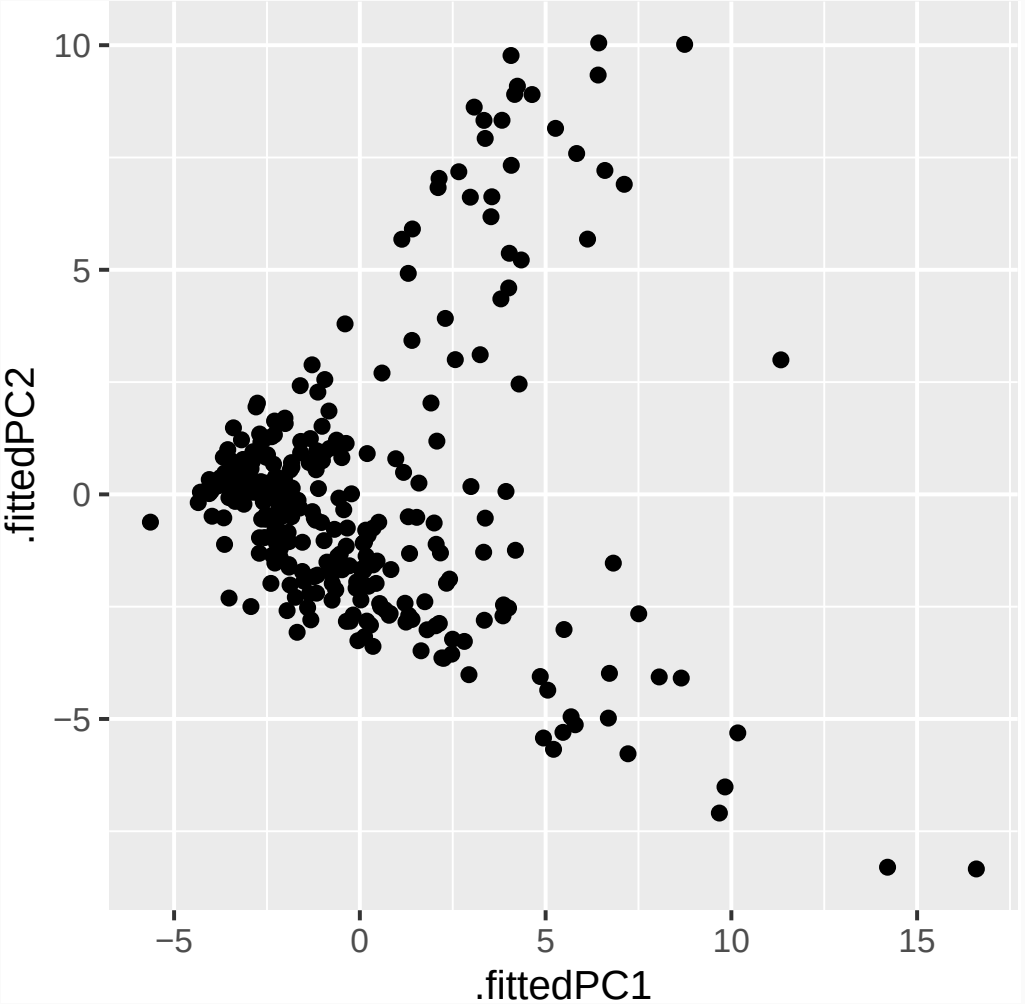
```
## # A tibble: 304 x 88
##    .rownames Region State Purpose trend_strength
##    <fct>     <chr>  <chr> <chr>           <dbl>
##  1 1         Adela~ SA    Busine~         0.451
##  2 2         Adela~ SA    Holiday         0.541
##  3 3         Adela~ SA    Other           0.743
##  4 4         Adela~ SA    Visiti~         0.433
##  5 5         Adela~ SA    Busine~         0.453
##  6 6         Adela~ SA    Holiday         0.512
##  7 7         Adela~ SA    Other           0.584
##  8 8         Adela~ SA    Visiti~         0.481
##  9 9         Alice~ NT    Busine~         0.526
## 10 10        Alice~ NT    Holiday         0.377
## # ... with 294 more rows, and 83 more variables:
## #   seasonal_strength_year <dbl>, spikiness <dbl>,
## #   linearity <dbl>, curvature <dbl>,
## #   seasonal_peak_year <dbl>, seasonal_trough_year <dbl>,
## #   acf1 <dbl>, acf10 <dbl>, diff1_acf1 <dbl>,
```

Principal components based on all features from the feasts package

Feature extraction and statistics

```
pcs %>% ggplot(aes(x=.fittedPC1, y=.fittedPC2)) +
  geom_point() + theme(aspect.ratio=1)
```

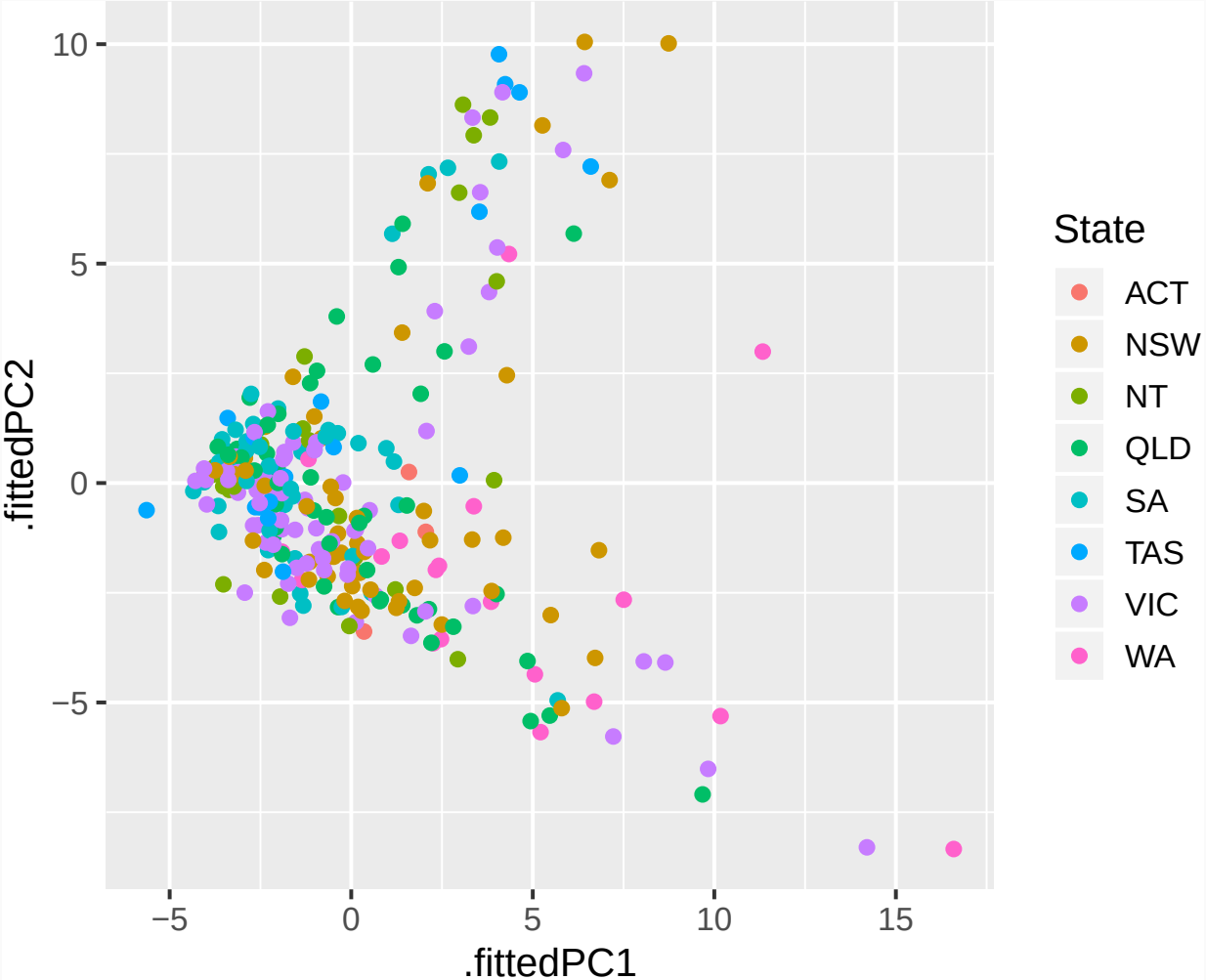
Principal components based on all features from the feasts package



Feature extraction and statistics

```
pcs %>% ggplot(aes(x=.fittedPC1, y=.fittedPC2, col=State)) +
  geom_point() + theme(aspect.ratio=1)
```

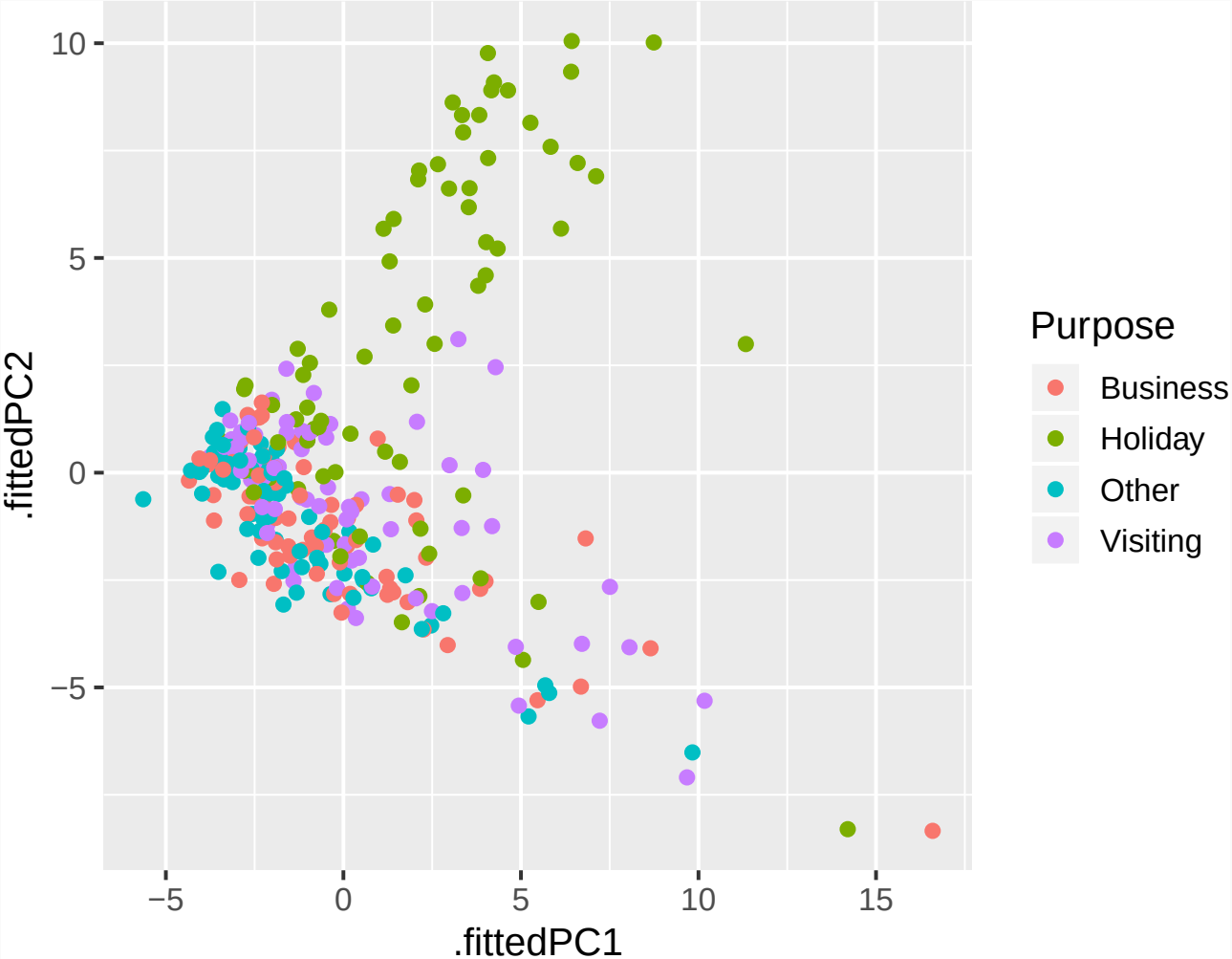
Principal components based on all features from the feasts package



Feature extraction and statistics

```
pcs %>% ggplot(aes(x=.fittedPC1, y=.fittedPC2, col=Purpose)) +
  geom_point() + theme(aspect.ratio=1)
```

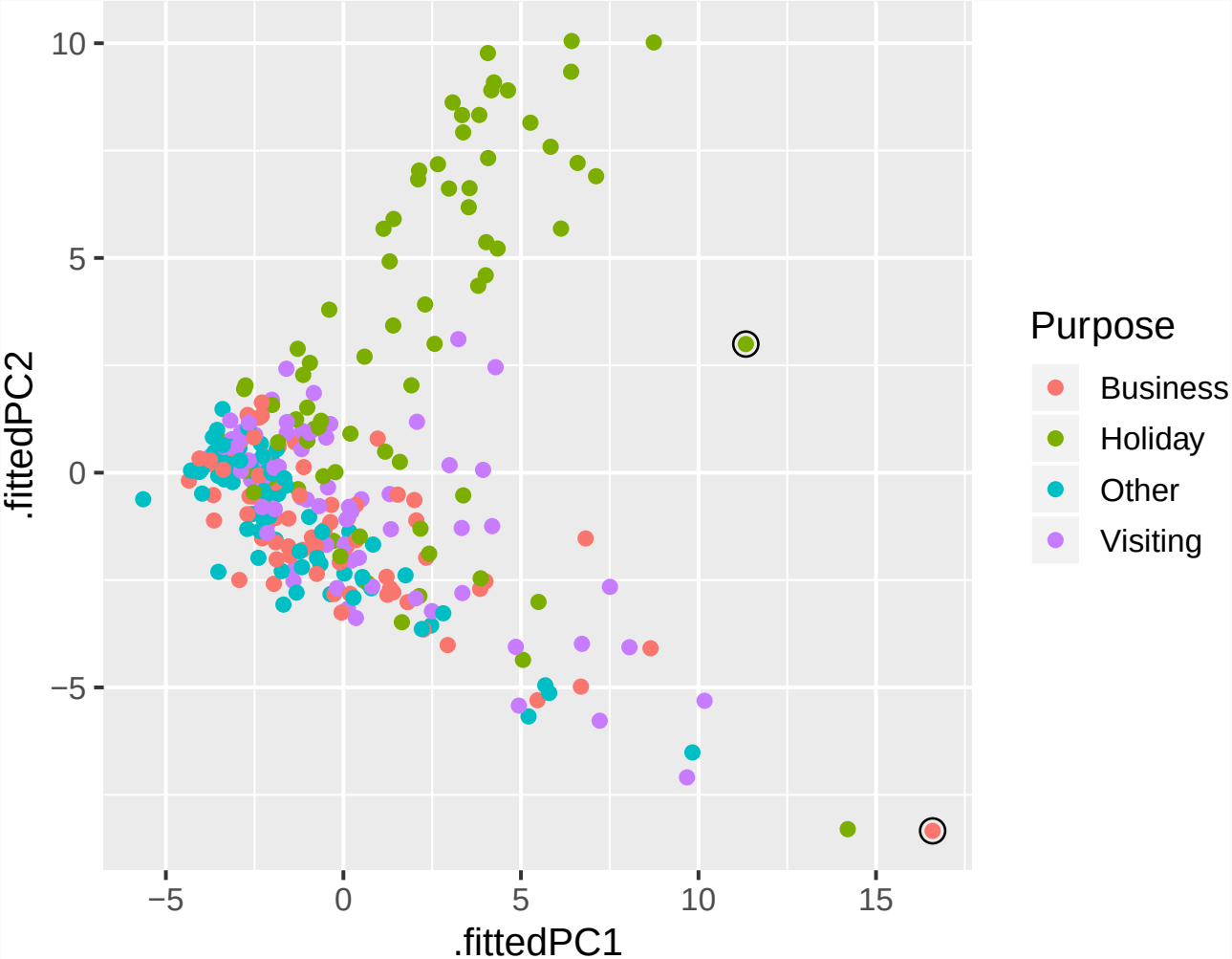
Principal components based on all features from the feasts package



Feature extraction and statistics

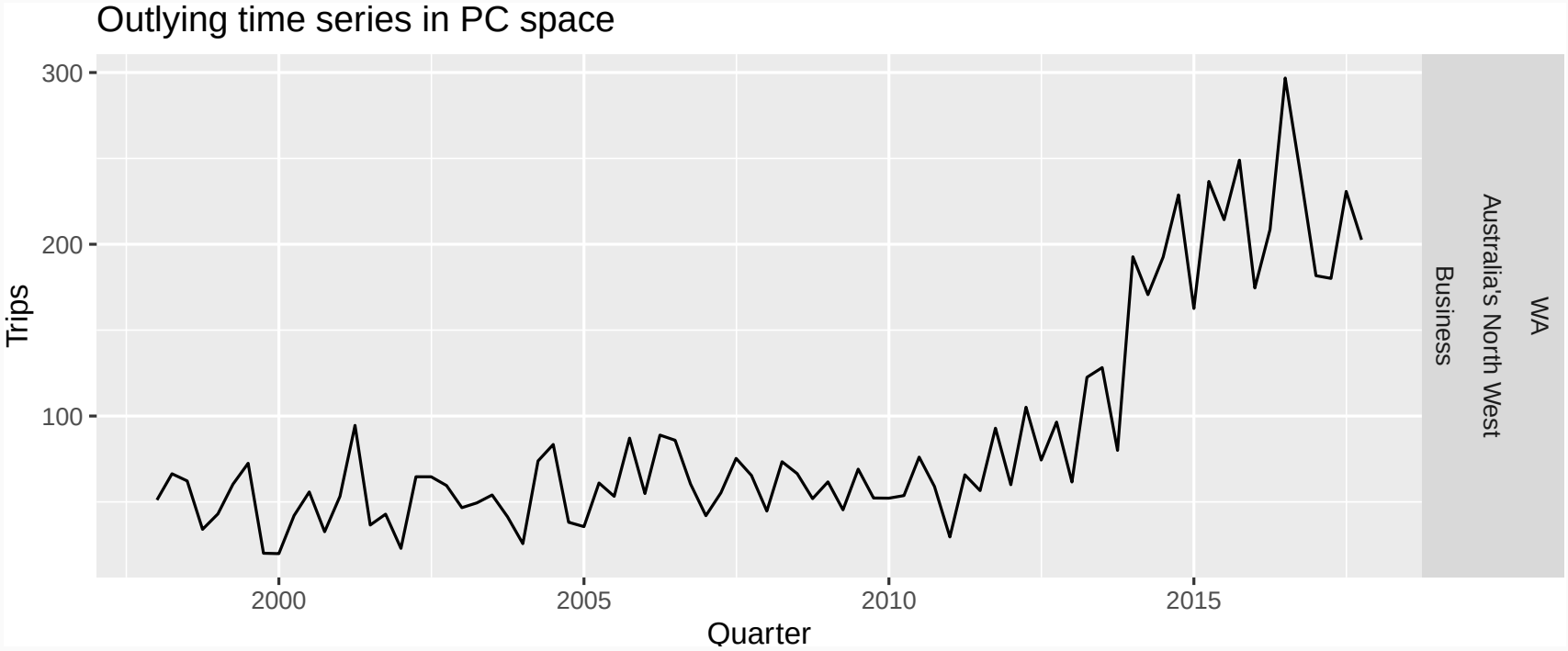
```
pcs %>% ggplot(aes(x=.fittedPC1, y=.fittedPC2, col=Purpose)) +
  geom_point() + theme(aspect.ratio=1)
```

Principal components based on all features from the feasts package



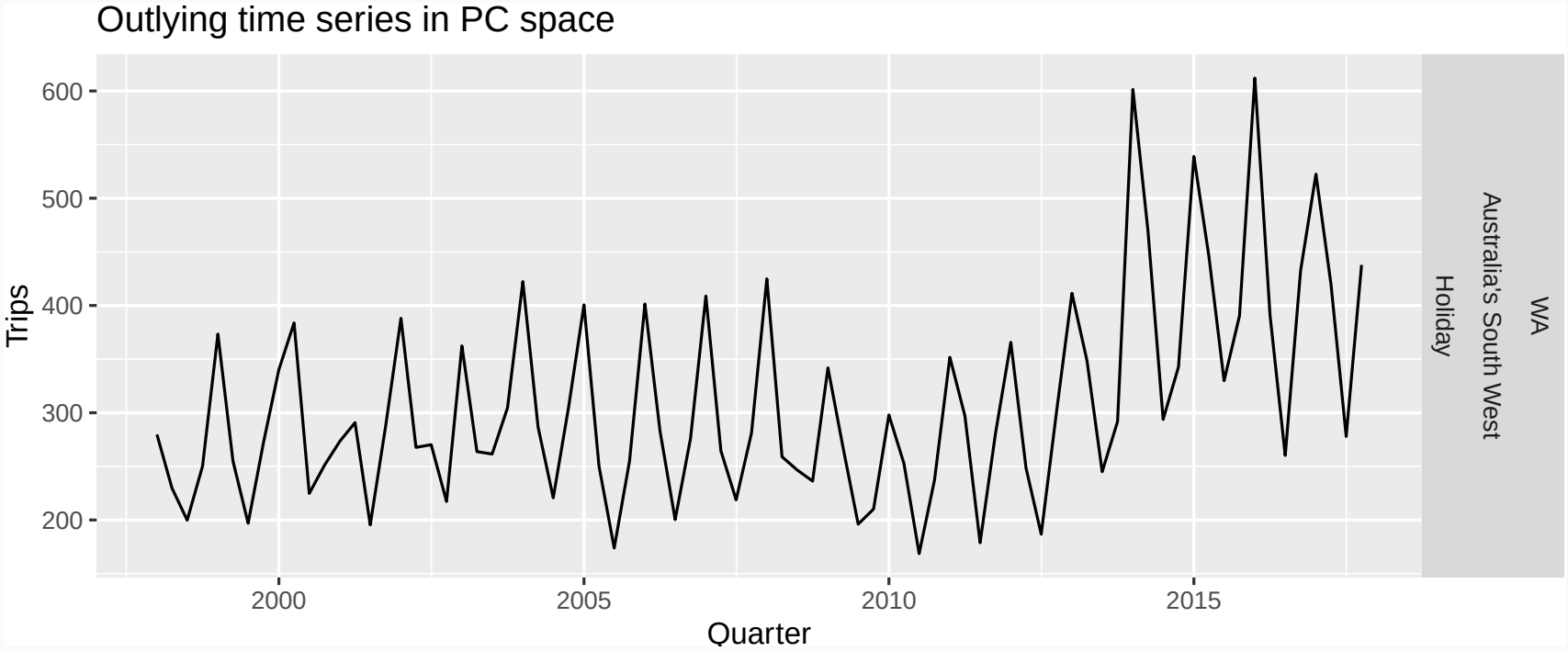
Feature extraction and statistics

```
pcs %>%
  filter(.fittedPC1 == max(.fittedPC1)) %>%
  left_join(tourism, by = c("State", "Region", "Purpose")) %>%
  ggplot(aes(x = Quarter, y = Trips)) +
    geom_line() +
    facet_grid(vars(State,Region,Purpose)) +
    ggtitle("Outlying time series in PC space") +
    theme(legend.position = "none")
```

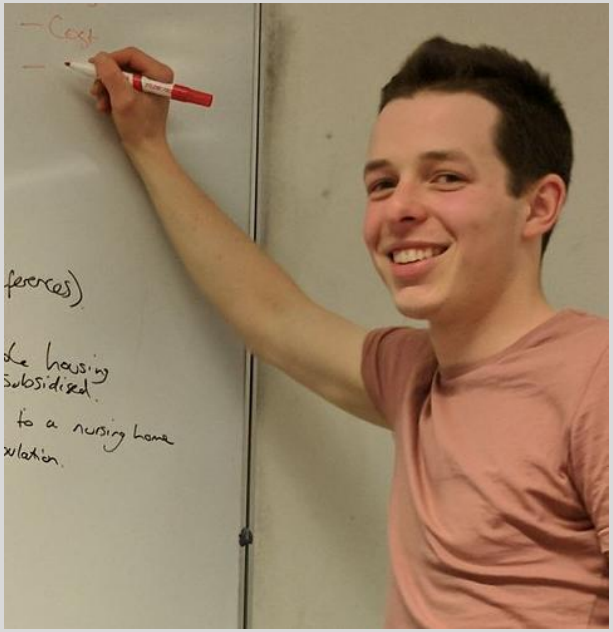


Feature extraction and statistics

```
pcs %>%
  filter(.fittedPC1 > 10 & .fittedPC2 > 2.5) %>%
  left_join(tourism, by = c("State", "Region", "Purpose")) %>%
  ggplot(aes(x = Quarter, y = Trips)) +
    geom_line() +
    facet_grid(vars(State,Region,Purpose)) +
    ggtitle("Outlying time series in PC space") +
    theme(legend.position = "none")
```



Acknowledgements



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Acknowledgements

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Monash Uni is now hiring in business analytics.

See **`bit.ly/monash-ba`** for details.