ETS

- Simple exponential smoothing : `fpp2::oil`

`fpp2::oil` 1965 2013 Saudi Arabia . 1996 simple exponential smoothing .

```
oil_1996 <- window(oil, start = 1996)
```

1996 Figure 1 .

```
autoplot(oil_1996) +
  labs(title = "Annual oil production in Saudi Arabia",
       y = NULL)
```

Figure 1: 1996 Saudi Arabia

`ses()` 2014 ~ 2016 .

```
ses(oil_1996, h = 3) %>%
  summary()
##
## Forecast method: Simple exponential smoothing
##
## Model Information:
## Simple exponential smoothing
##
## Call:
##  ses(y = oil_1996, h = 3)
##
##   Smoothing parameters:
##     alpha = 0.8339
##
##   Initial states:
##     l = 446.5868
##
##   sigma:  29.8282
##
```

```
##       AIC     AICc      BIC
## 178.1430 179.8573 180.8141
##
## Error measures:
##                    ME     RMSE     MAE      MPE     MAPE      MASE        ACF1
## Training set 6.401975 28.12234 22.2587 1.097574 4.610635 0.9256774 -0.03377748
##
## Forecasts:
##      Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
## 2014       542.6806 504.4541 580.9070 484.2183 601.1429
## 2015       542.6806 492.9073 592.4539 466.5589 618.8023
## 2016       542.6806 483.5747 601.7864 452.2860 633.0752
```

Level $\alpha = 0.8339$ level . Figure 2 .

```
ses(oil_1996, h = 3) %>%
  autoplot() +
  labs(y = NULL)
```

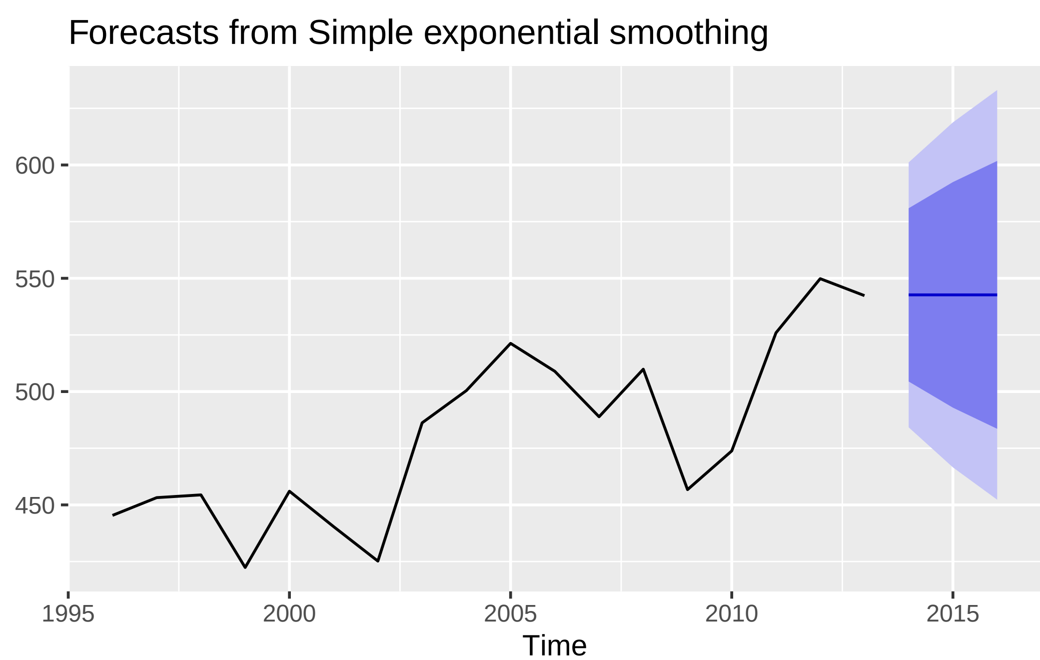


Figure 2: 1996 Saudi Arabia 2014

level , `h` . 80% , 95% . .

- Trend method : `fpp2::ausair`

`fpp2::ausair` 1970 2016 . Holt's linear trend damped Holt's trend .

Figure 3 . .

```r
autoplot(ausair) +
  labs(title = "Air Transport Passengers Australia",
       y = NULL)
```

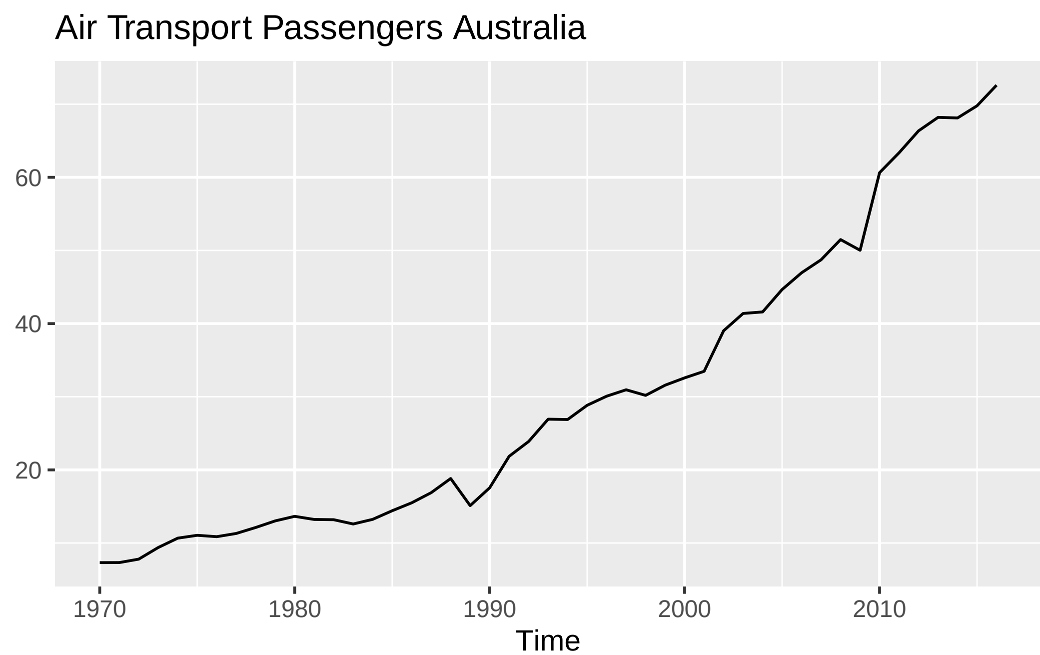


Figure 3: 1970 2016

Holt's linear trend `holt()` , 15 Figure 4 .

```r
holt(ausair, h = 15) %>%
  autoplot()
```

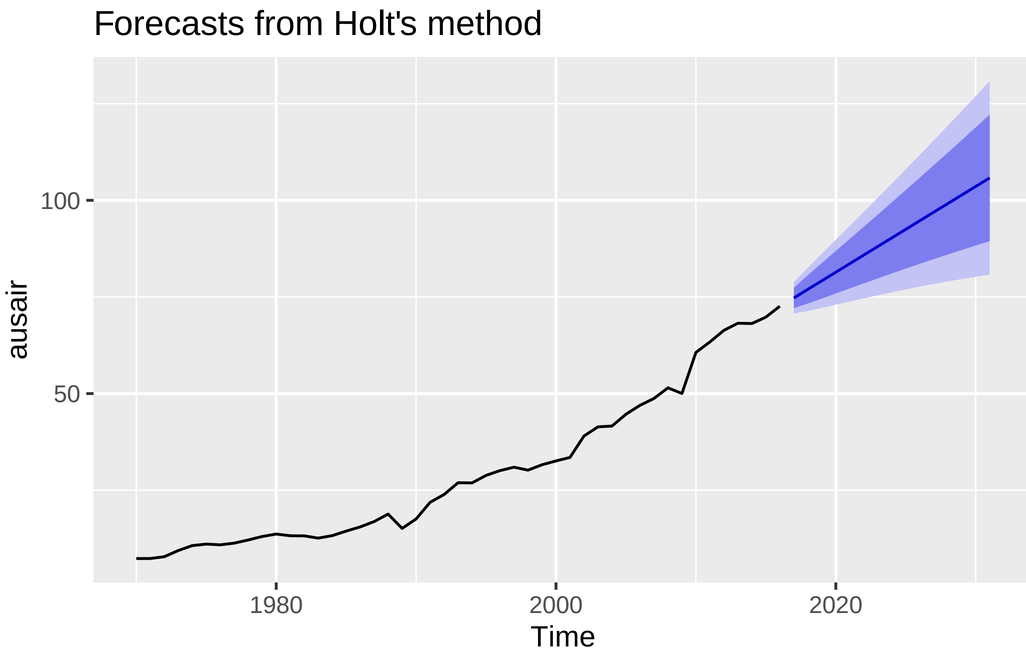


Figure 4: `ausair` Holt's linear trend method

Damped Holt's trend . Figure 5 .

```r
holt(ausair, h = 15, damped = TRUE) %>%
  autoplot()
```

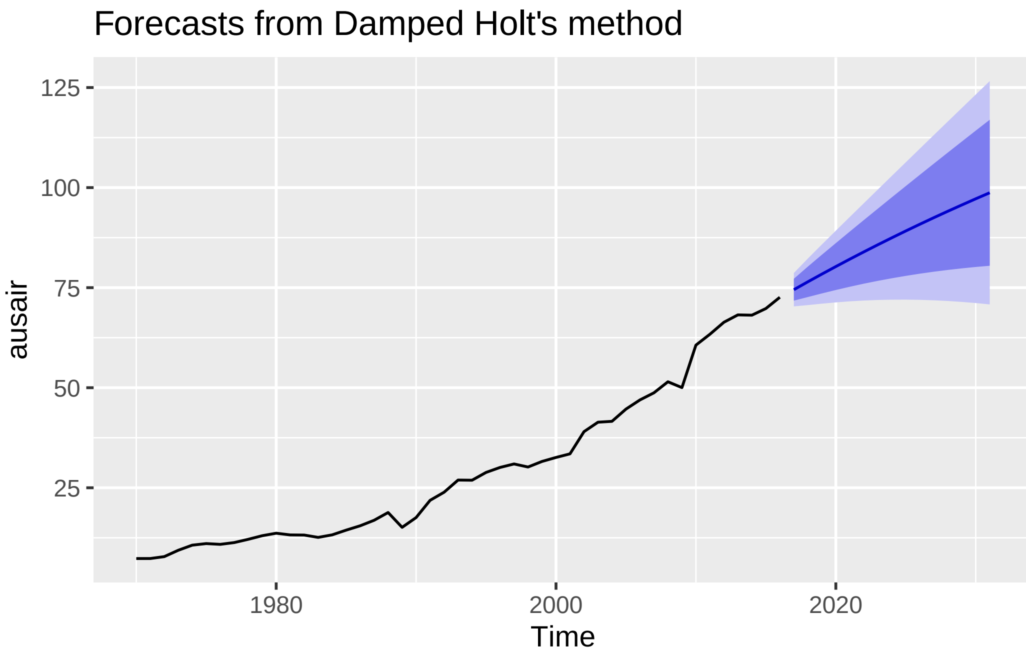


Figure 5: `ausair` damped Holt's trend method

Figure 4 Holt's linear trend method , damped Holt's trend method Figure 5 .

- Holt-Winters' seasonal method : `fpp2::austourists`

`austourists` 199 2015 . Figure 6 .

```
autoplot(austourists) +
  labs(y = NULL, title = "International Tourists to Australia")
```

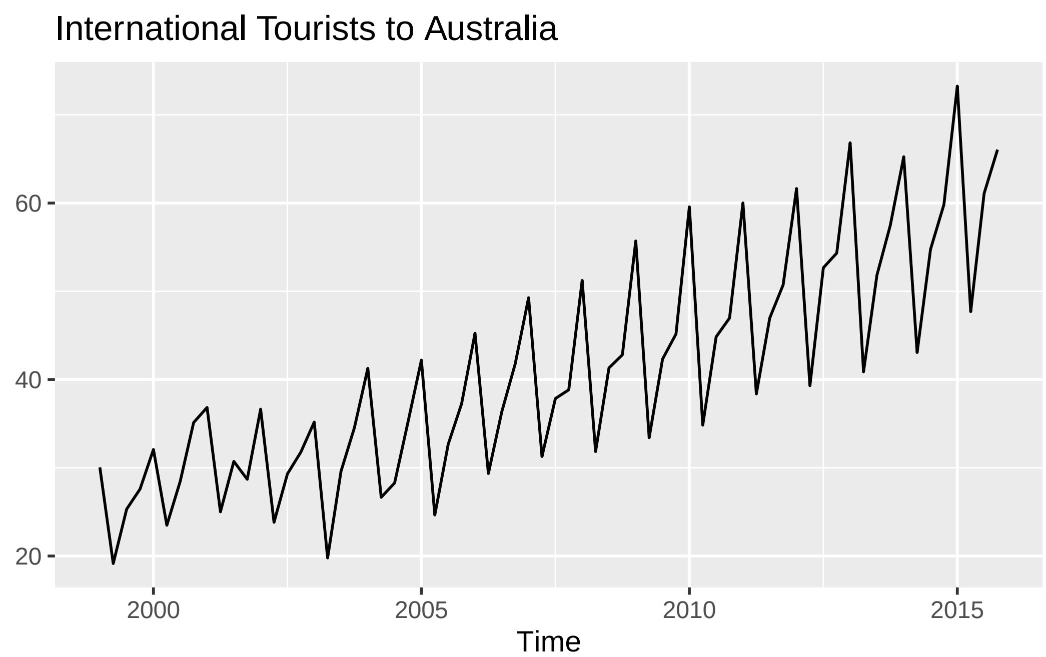


Figure 6: 199 2015

Holt-Winters' seasonal . Figure 7 .

```
hw(austourists) %>%
  autoplot() + labs(y = NULL)
```

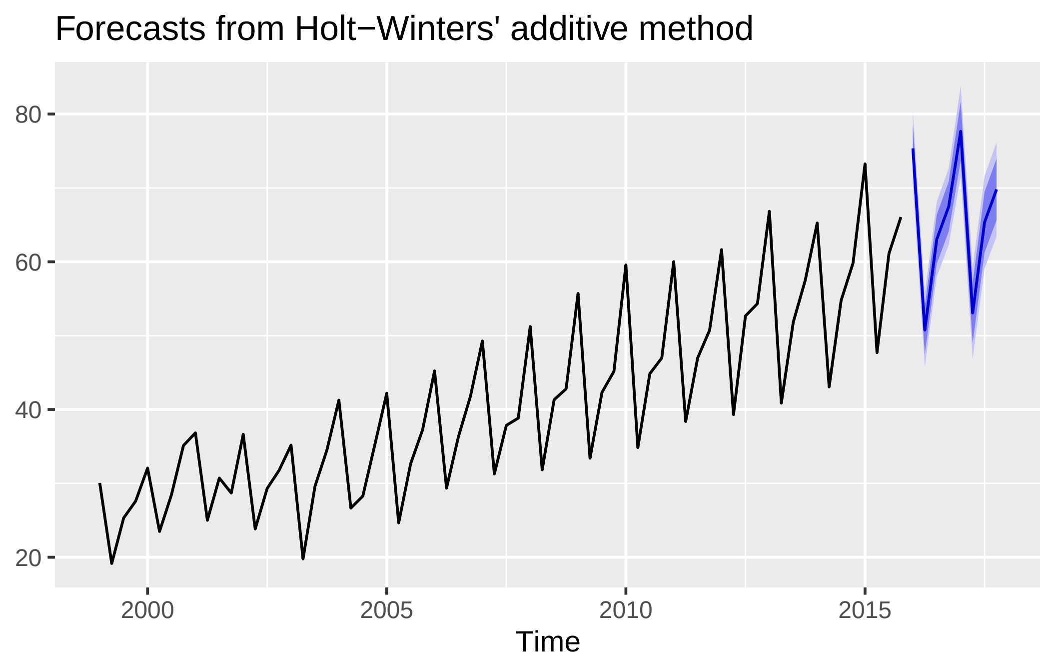


Figure 7: `austourists` Holt-Winters' additive seasonal method

Figure 8 .

```r
hw(austourists, seasonal = "multiplicative") %>%
  autoplot() + labs(y = NULL)
```

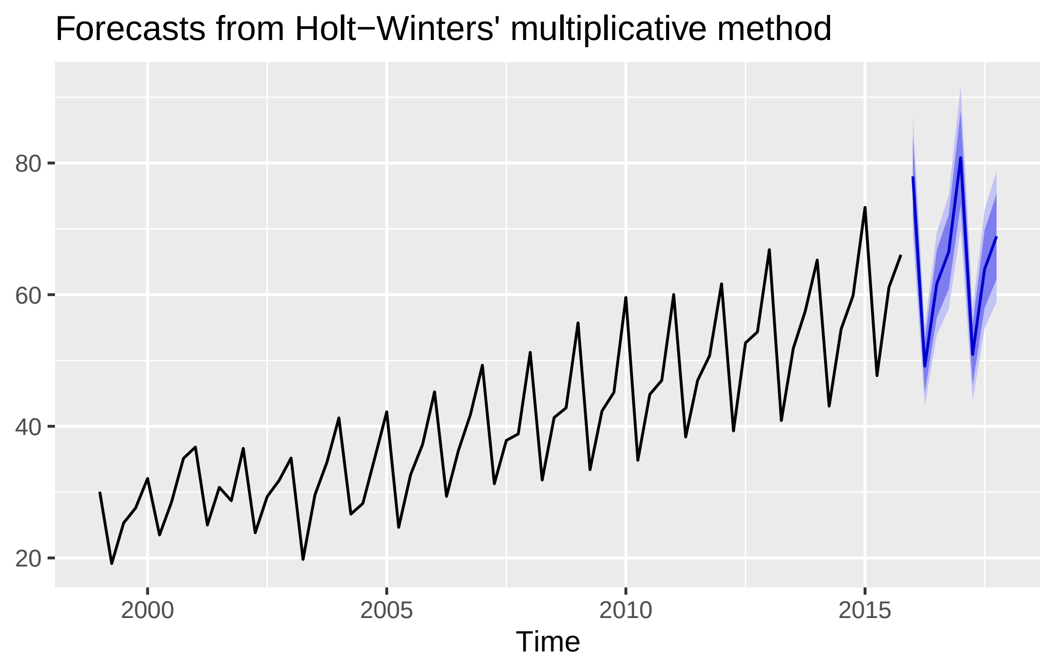


Figure 8: `austourists` Holt-Winters' multiplicative seasonal method

ETS

- 1: 1970 2016 (`fpp2::ausair`)

`fpp2::ausair` 1970 2016 . 1970 2011 training data , 2012 test data .

```
train_air <- window(ausair, end = 2011)
test_air <- window(ausair, start = 2012)
```

`train_air` `test_air` Figure 9 . `test_air` .

```
autoplot(window(ausair, end = 2012)) +
  autolayer(window(ausair, start = 2012), size = .8) +
  labs(y = NULL, x = NULL) +
  theme(legend.position = "none")
```

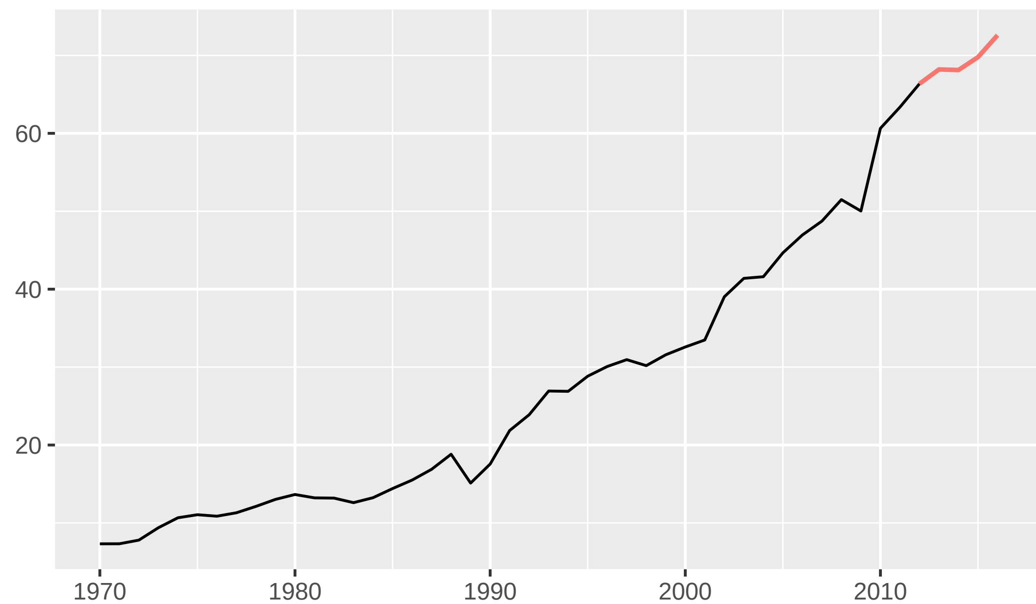


Figure 9: `ausair`

`ets()` ETS , .

```
fit_air <- ets(train_air)
fit_air
## ETS(M,A,N)
##
## Call:
##  ets(y = train_air)
##
##   Smoothing parameters:
##     alpha = 0.9999
##     beta  = 0.024
##
##   Initial states:
##     l = 6.5399
##     b = 0.7358
##
##   sigma:  0.08
##
##      AIC     AICc      BIC
## 206.1828 207.8495 214.8712
```

ETS(M,A,N) . , additive multiplicative , . $\alpha = 0.9999$, $\beta = 0.024$. level , .

ETS Figure 10 . , level . .

```r
autoplot(fit_air)
```

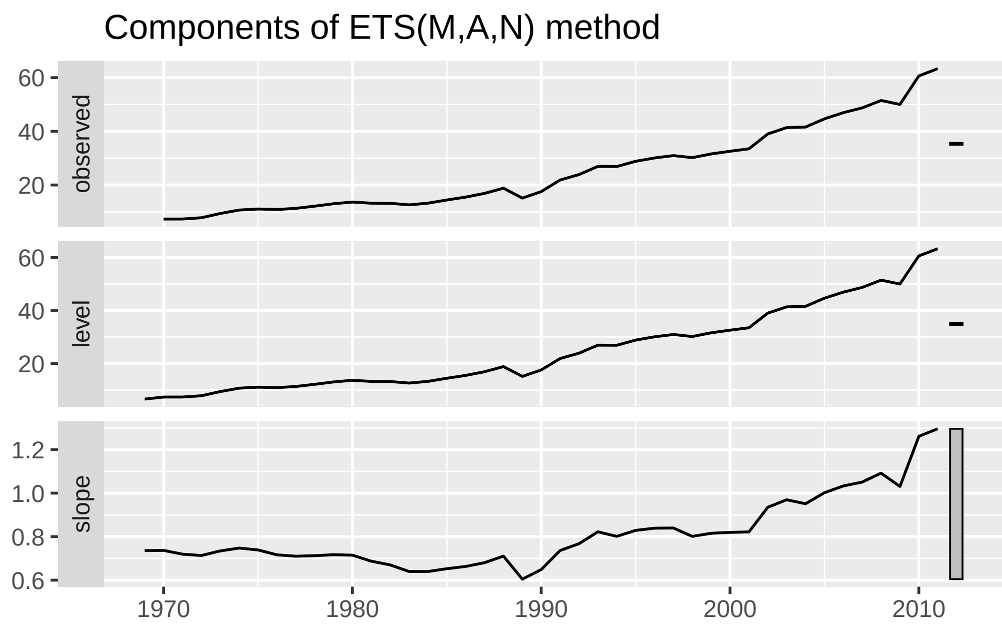
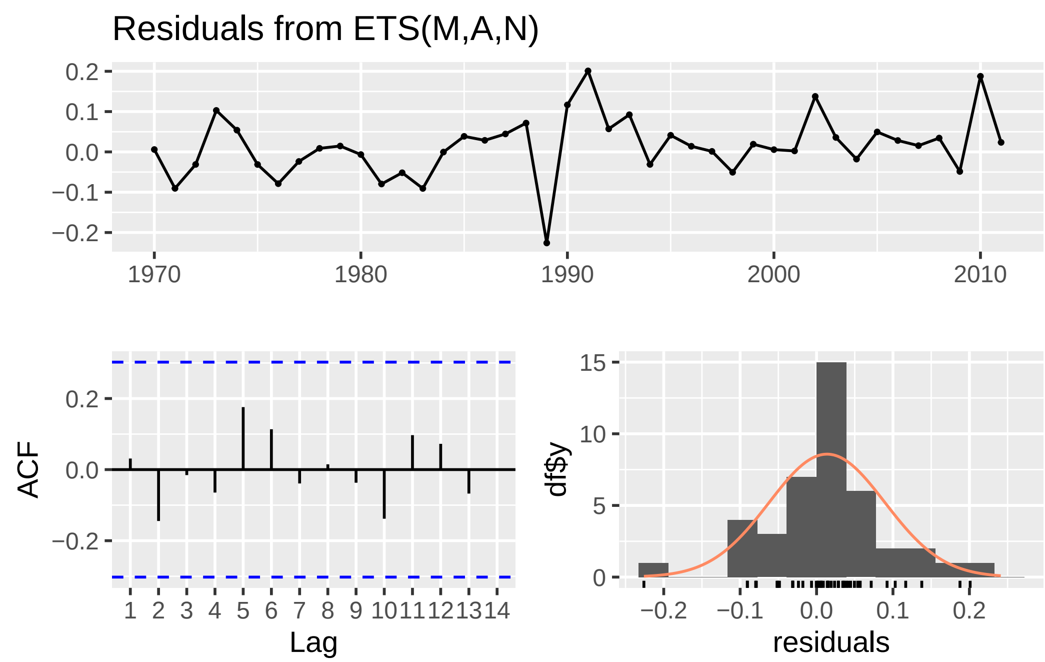


Figure 10: ETS

checkresiduals() . .

```r
checkresiduals(fit_air)
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ETS(M,A,N)
## Q* = 3.5236, df = 8, p-value = 0.8973
##
## Model df: 0.   Total lags used: 8
```

.

```r
fc_air <- forecast(fit_air, h = length(test_air))
accuracy(fc_air, test_air)
##                     ME     RMSE     MAE       MPE     MAPE      MASE
## Training set 0.5550369 2.138179 1.31460 0.7893247 5.399428 0.7649321
## Test set     1.7629504 1.888573 1.76295 2.5419343 2.541934 1.0258159
##                     ACF1 Theil's U
## Training set -0.09163575        NA
## Test set     -0.22513230  1.034042
```

. `autoplot()` `forecast()` `fc_air` training data . `include` training data . `include = 0` . Figure 11 .

```r
library(patchwork)
p1 <- autoplot(fc_air) +
  autolayer(test_air, color = "red", size = .8) +
  labs(y = NULL, x = NULL)
p2 <- autoplot(fc_air, include = 0) +
  autolayer(test_air, color = "red", size=.8) +
  labs(y = NULL, x = NULL)
p1 + p2
```

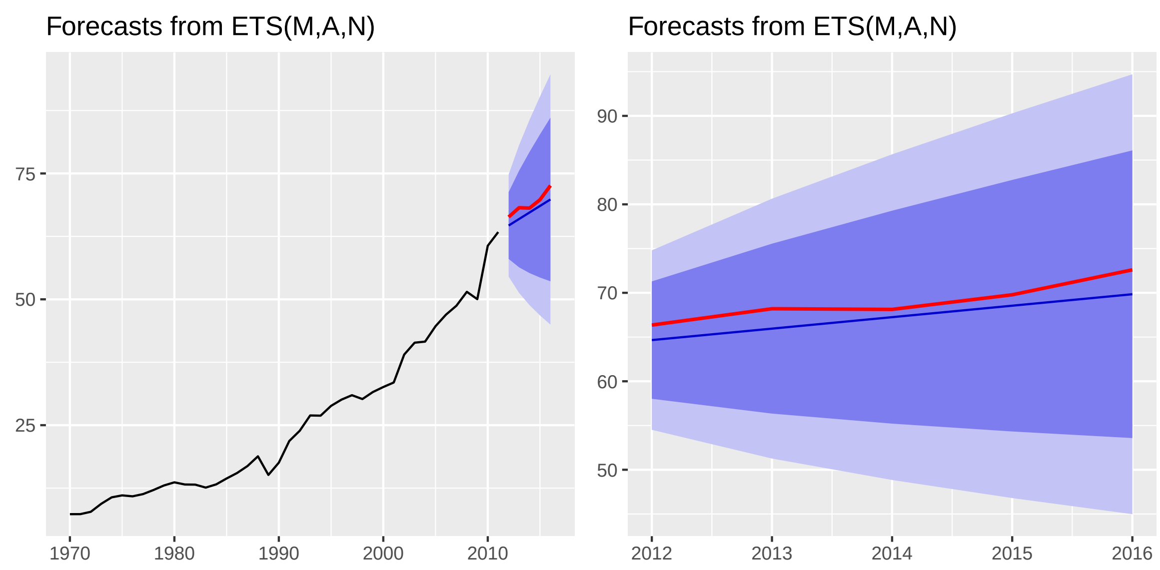


Figure 11: `fpp2::ausair` ETS

- 2: 1999 2015 (`fpp2::austourists`)

`austourists` 1999 2015 . 2013 4 training data 2014 1 test data .

```r
train_tour <- window(austourists, end = c(2013, 4))
test_tour <- window(austourists, start = c(2014, 1))
```

Figure 12 . Test data . , . .

```r
autoplot(window(austourists, end = c(2014,1))) +
  autolayer(window(austourists, start = c(2014,1)), size = .8) +
```

```
  labs(y = NULL) +
  theme(legend.position = "none")
```

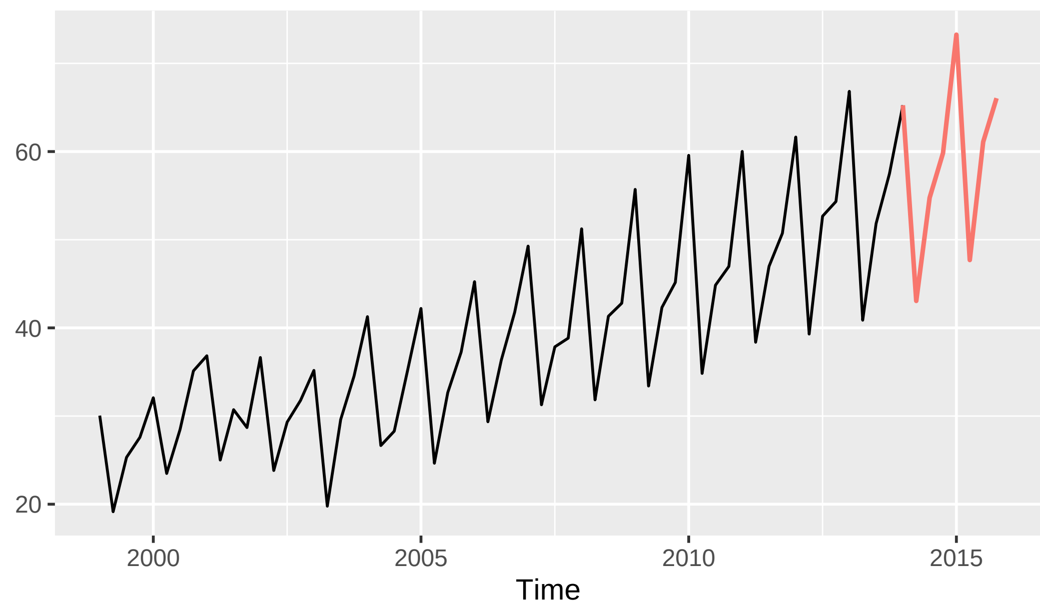


Figure 12: `austourists`

`ets()` .

```
fit_tour <- ets(train_tour)
fit_tour
## ETS(M,A,M)
##
## Call:
##  ets(y = train_tour)
##
##   Smoothing parameters:
##     alpha = 0.4189
##     beta  = 1e-04
##     gamma = 1e-04
##
##   Initial states:
##     l = 24.2672
##     b = 0.5179
```

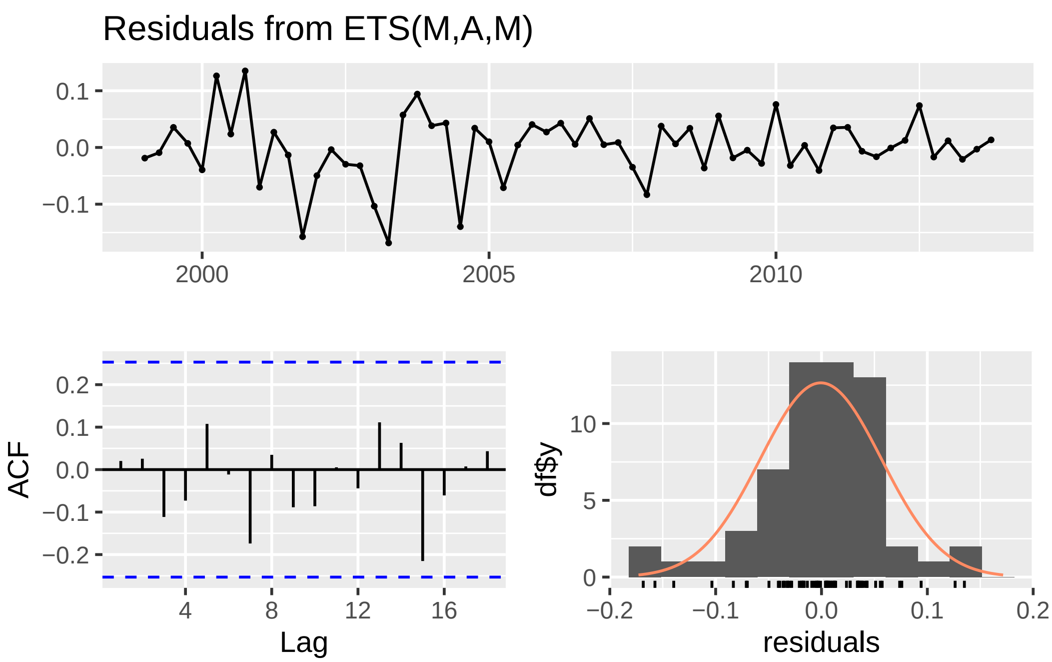
```
##     s = 1.0367 0.9578 0.7697 1.2358
##
##   sigma:  0.0612
##
##      AIC     AICc      BIC
## 353.3882 356.9882 372.2373
```

ETS(M,A,M) . . ETS
. `ets()` Box_Cox `lambda` 0 .

```
fit_lntour <- ets(train_tour, lambda = 0)
fit_lntour
## ETS(A,A,A)
##
## Call:
##  ets(y = train_tour, lambda = 0)
##
##   Box-Cox transformation: lambda= 0
##
##   Smoothing parameters:
##     alpha = 0.337
##     beta  = 1e-04
##     gamma = 0.0137
##
##   Initial states:
##     l = 3.2161
##     b = 0.0122
##     s = 0.055 -0.0254 -0.2477 0.2181
##
##   sigma:  0.0639
##
##       AIC      AICc       BIC
## -75.06808 -71.46808 -56.21898
```

`fit_tour` .

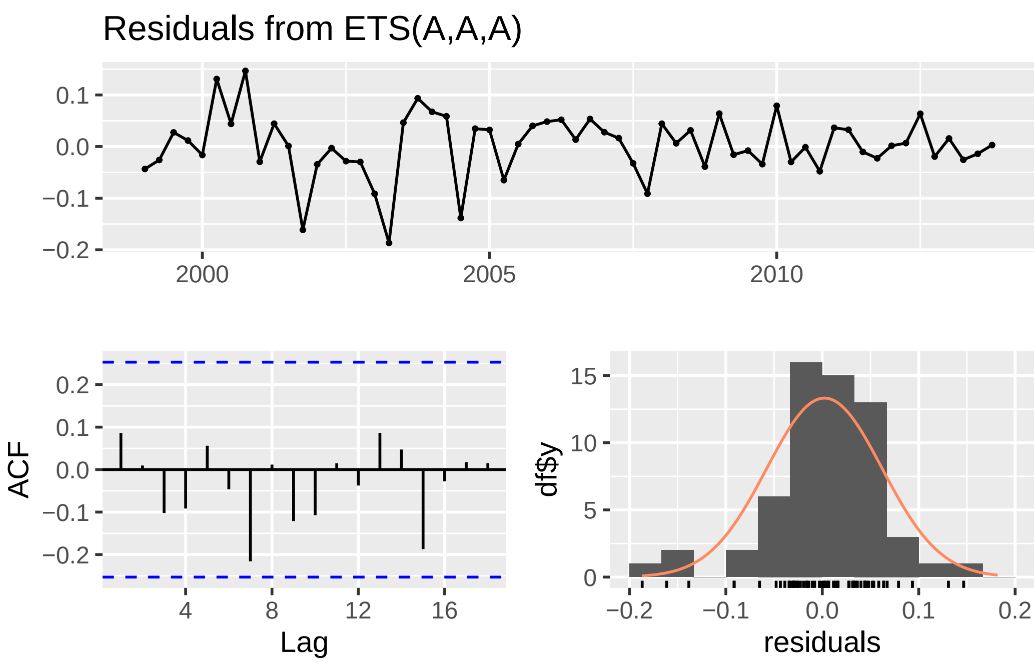
```
checkresiduals(fit_tour)
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ETS(M,A,M)
## Q* = 4.2317, df = 8, p-value = 0.8356
##
## Model df: 0.   Total lags used: 8
```

fit_lntour .

```
checkresiduals(fit_lntour)
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ETS(A,A,A)
## Q* = 5.355, df = 8, p-value = 0.719
##
## Model df: 0.   Total lags used: 8
```

. , .

```
fc_tour <- forecast(fit_tour, h = length(test_tour))
fc_lntour <- forecast(fit_lntour, h = length(test_tour))
```

```
accuracy(fc_tour, test_tour)
##                        ME     RMSE      MAE        MPE     MAPE      MASE
## Training set 0.004642325 1.966538 1.474615 -0.4054666 4.196005 0.5206241
## Test set     1.541295202 2.989673 2.414226  2.6022154 3.958845 0.8523613
##                    ACF1 Theil's U
## Training set -0.0243205        NA
## Test set      0.5001355 0.2077632
accuracy(fc_lntour, test_tour)
##                      ME     RMSE      MAE        MPE     MAPE      MASE
```

```
## Training set 0.1640202 2.014686 1.562901 0.04389638 4.399828 0.5517943
## Test set     0.6115065 2.128486 1.722829 1.03590923 2.853023 0.6082580
##                    ACF1 Theil's U
## Training set 0.01619145        NA
## Test set     0.47705974 0.1348746
```

ETS(A,A,A) `fit_lntour` test data . Figure 13 . `autolayer()` `PI = FALSE` . . .

```
library(patchwork)
p1 <- autoplot(train_tour) +
  autolayer(test_tour, series = "Test data") +
  autolayer(fc_tour, PI = FALSE, series = "ETS(M,A,M)") +
  autolayer(fc_lntour, PI = FALSE, series = "ETS(A,A,A)") +
  labs(y = NULL, x = NULL, color = NULL) +
  theme(legend.position = "top")

p2 <- autoplot(test_tour, series = "Test data", size = .8) +
  autolayer(fc_tour, PI = FALSE, series = "ETS(M,A,M)",
            size = .8) +
  autolayer(fc_lntour, PI = FALSE, series = "ETS(A,A,A)",
            size = .8) +
  labs(y = NULL, x = NULL, color = NULL) +
  theme(legend.position = "top")

p1 + p2
```

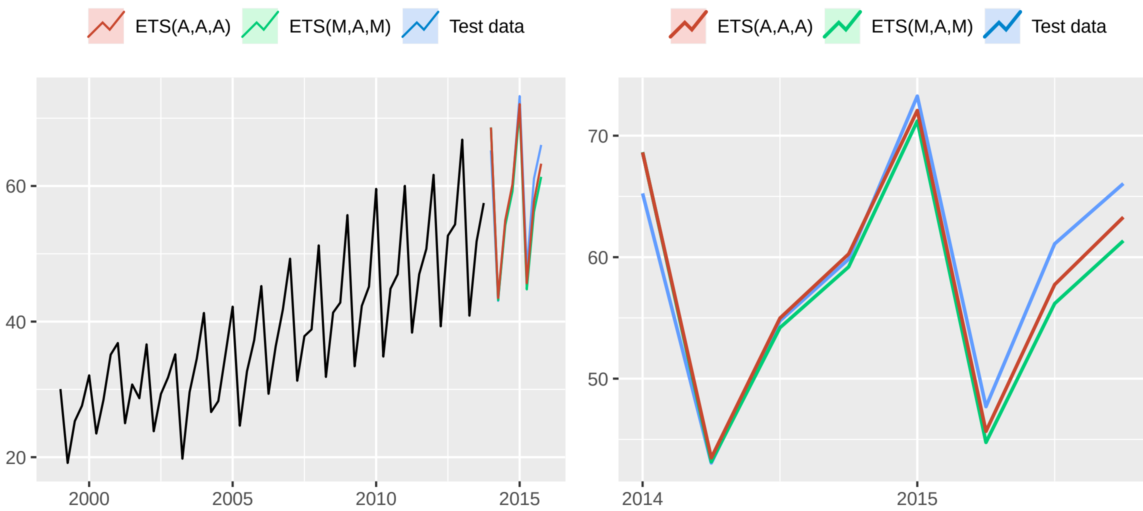


Figure 13: `austourists`

ETS(A,A,A) `fit_lntour` test data Figure 14 .

```
library(patchwork)
p1 <- autoplot(fc_lntour) +
  autolayer(test_tour, color = "red", size = .8) +
  labs(x = NULL, y = NULL)
p2 <- autoplot(fc_lntour, include = 0) +
  autolayer(test_tour, color = "red", size = .8) +
  labs(y = NULL, x = NULL) +
  scale_x_continuous(breaks = c(2014.0, 2014.5, 2015.0, 2015.5),
                     labels = c("2014.Q1", "2014.Q3", "2015.Q1",
                                "2015.Q3"))
p1 + p2
```

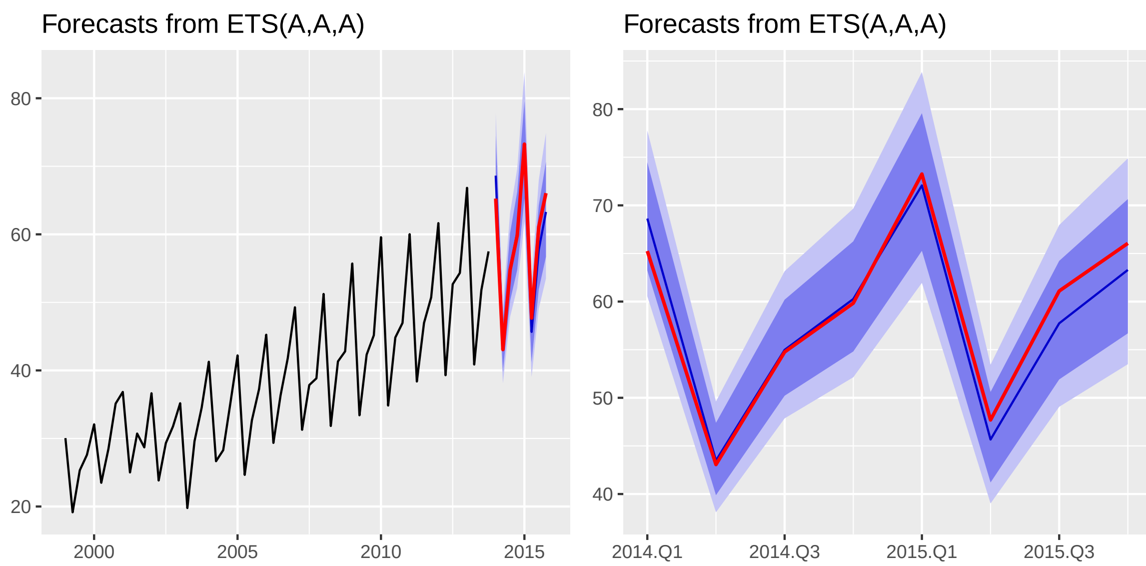


Figure 14: `austourists`

- 3: 1965 1 1992 7 (`fma::dole`)

`fma::dole` 1965 1 1992 7 . 2 test data .

```
train_d <- window(dole, end = c(1990, 7))
test_d <- window(dole, start = c(1990, 8))
```

Figure 15 . Test data . 1990 , test data . .

```
autoplot(train_d) +
  autolayer(test_d, show.legend=FALSE, size = .8) +
  labs(y = NULL, x = NULL)
```

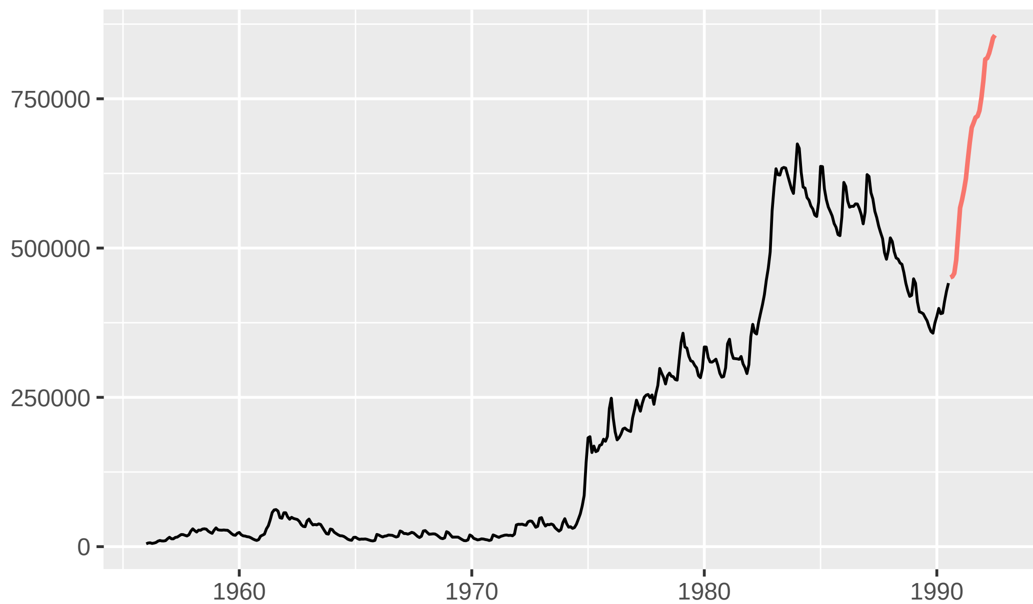


Figure 15: `dole`

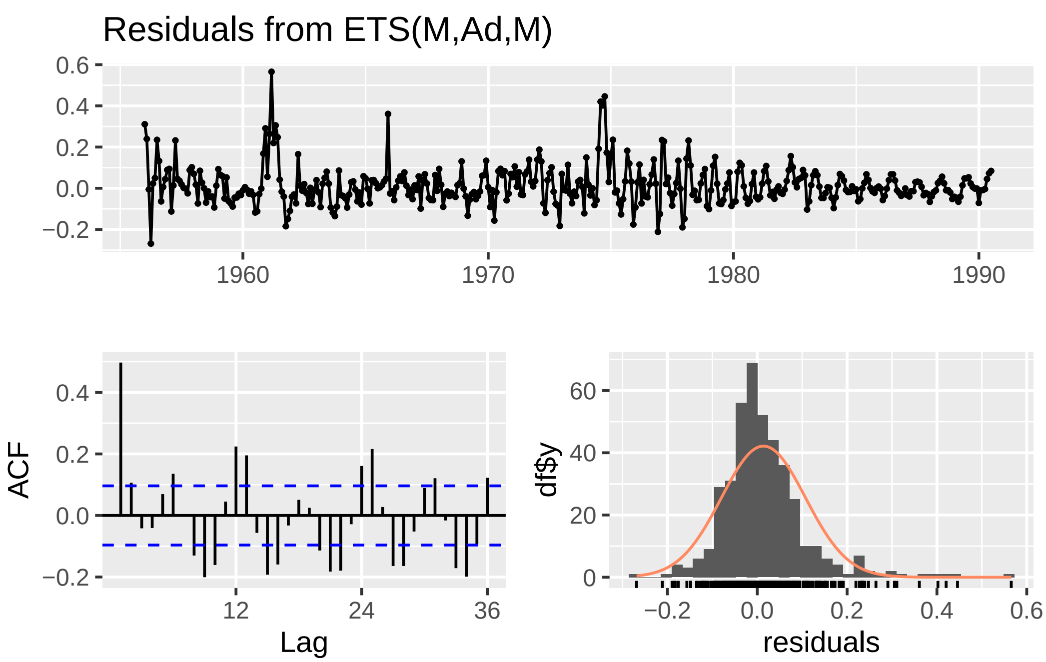
ETS .

```
fit_d <- ets(train_d)
fit_d
## ETS(M,Ad,M)
##
## Call:
##  ets(y = train_d)
##
##   Smoothing parameters:
##     alpha = 0.7057
##     beta  = 0.1262
##     gamma = 0.2942
##     phi   = 0.8701
##
##   Initial states:
##     l = 2693.6084
##     b = 838.4198
##     s = 1.0776 0.9108 0.9286 0.9993 1.0254 1.0275
##            1.0028 0.9466 1.0225 0.9982 1.0038 1.0568
##
```

```
##   sigma:  0.0965
##
##      AIC     AICc      BIC
## 9930.864 9932.591 10003.373
```

, . , (point forecast) , .

```r
checkresiduals(fit_d)
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ETS(M,Ad,M)
## Q* = 270.13, df = 24, p-value < 2.2e-16
##
## Model df: 0.   Total lags used: 24
```

.

```r
fc_d <- forecast(fit_d, h = length(test_d))
accuracy(fc_d, test_d)
##                      ME      RMSE        MAE        MPE      MAPE      MASE
## Training set    307.438  16094.96   9474.828  0.5940649  6.112239 0.2965093
## Test set     208048.806 234353.38 208048.806 28.7917875 28.791788 6.5107678
##                   ACF1 Theil's U
## Training set 0.5103798        NA
## Test set     0.8895083  8.715368
```

MASE . Figure 16 .

```r
autoplot(fc_d) +
  autolayer(test_d, color = "red", size = .8) +
  labs(y = NULL, x = NULL)
```

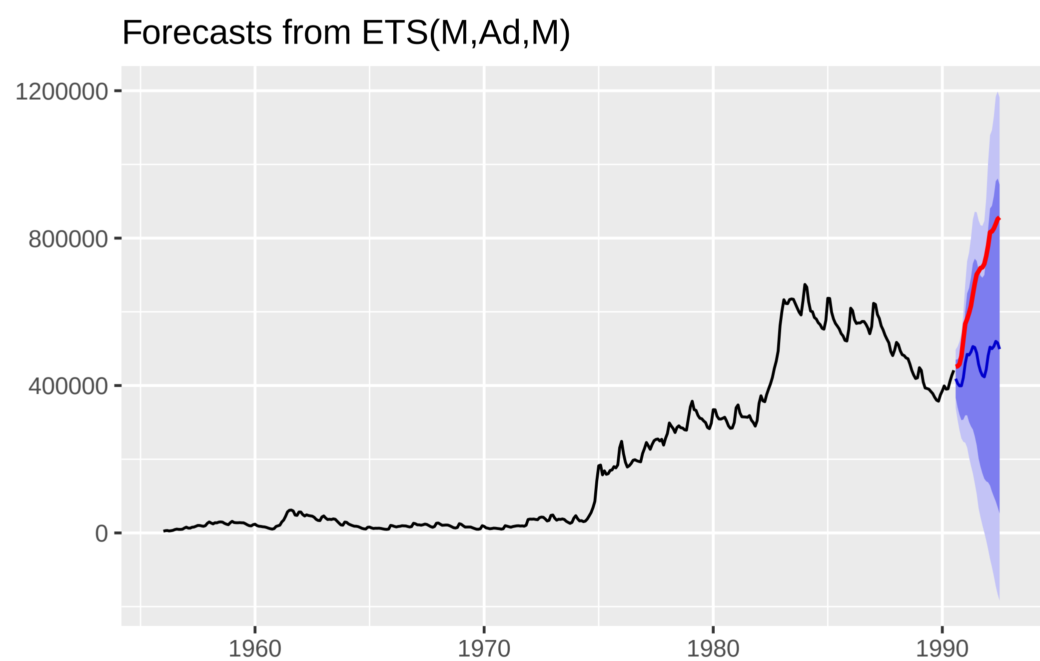


Figure 16: `dole`

. .

Test data test data . , training data . test data . 1 test data . `subset()` . `end` `start` .

```r
train_d_1 <- subset(dole, end = length(dole) - 12)
test_d_1 <- subset(dole, start = length(dole) - 11)
```

training data 1 . .

```r
fc_d_1 <- train_d_1 %>%
  ets() %>%
  forecast(h = length(test_d_1))
```

```r
accuracy(fc_d_1, test_d_1)
##                     ME     RMSE      MAE       MPE     MAPE      MASE      ACF1
## Training set  419.4624 18184.20 10856.63 0.5111136 6.268750 0.3014767 0.5191139
## Test set     5143.1303 46330.29 40948.53 1.0361996 5.319935 1.1370959 0.8678915
##              Theil's U
## Training set        NA
## Test set      2.792915
```

Figure 17) .

```r
library(patchwork)
p1 <- autoplot(fc_d_1) +
  autolayer(test_d_1, color = "red", size = .8) +
  labs(y = NULL, x = NULL)
p2 <- autoplot(fc_d_1, include = 0) +
  autolayer(test_d_1, color = "red", size = .8) +
  labs(y = NULL, x = NULL)
p1 + p2
```

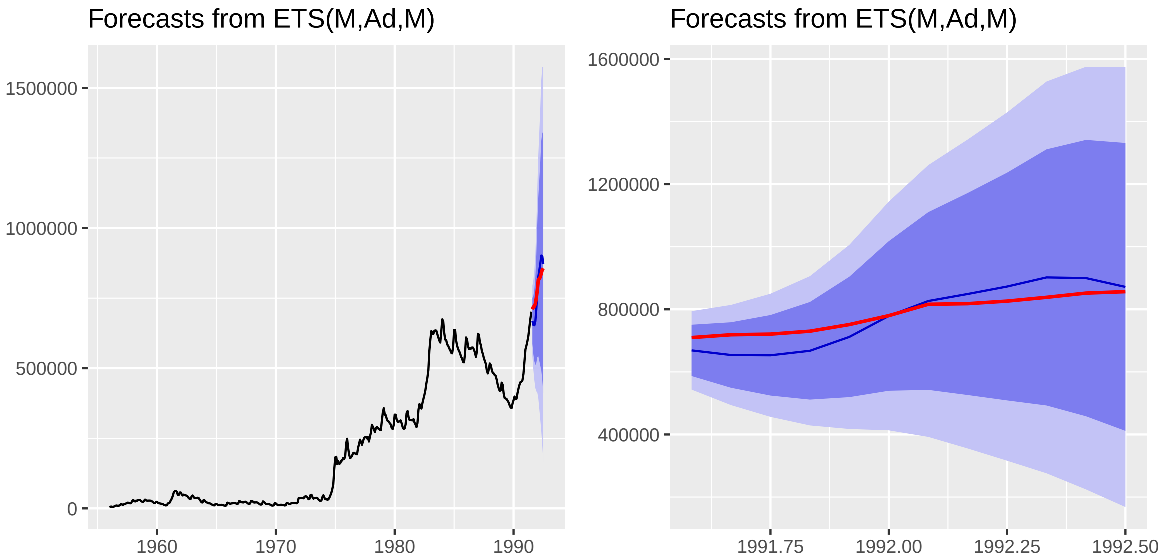


Figure 17: `dole`

- 4: 2014 4 30 1 Hyndsight (`fpp2::hyndsight`)

`hyndsight` 2014 4 30 1 Hyndman . Figure 18 .

```
autoplot(hyndsight) + labs(x = NULL, y = NULL)
```

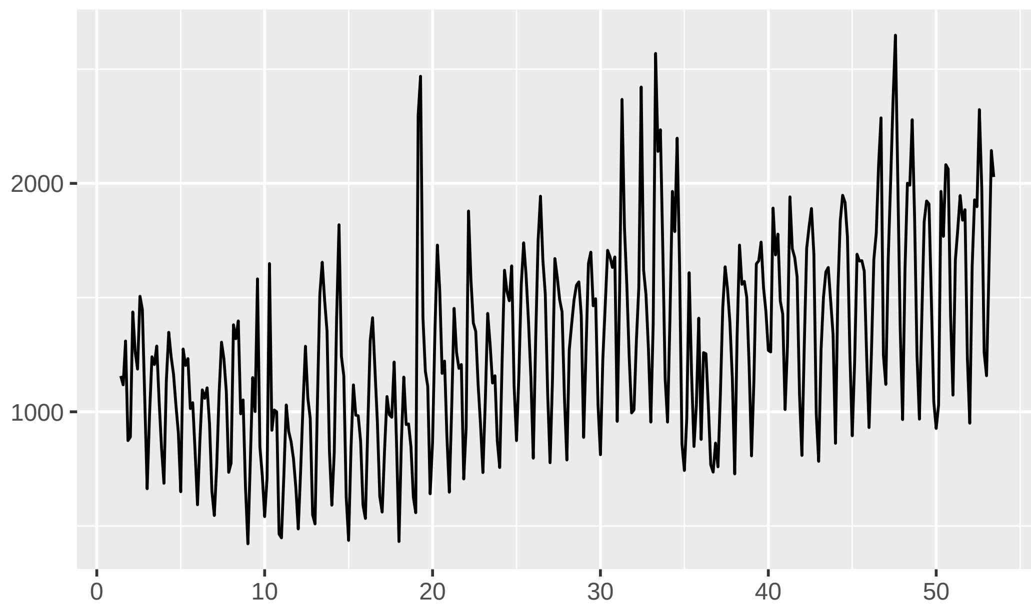


Figure 18: `hyndsight`

$m = 7$. 2014 4 30 .

```r
lubridate::wday(as.Date("2014-4-30"), label = TRUE)
## [1]
## Levels:  <  <  <  <  <  <
```

```r
start(hyndsight); end(hyndsight)
## [1] 1 4
## [1] 53  4
```

2014 4 30 , 1 4 ( ) 53 4 ( ) . Training data 1 4 48 4 , test data 48 5 53 4 5 .

`window()` , `subset()` . , 35 test data .

```r
train_hyn <- subset(hyndsight, end = length(hyndsight)-35)
test_hyn <- subset(hyndsight, start = length(hyndsight)-34)
```

ETS . , .

```r
fit_hyn <- ets(train_hyn)
fit_hyn
## ETS(A,N,A)
##
## Call:
##  ets(y = train_hyn)
##
##   Smoothing parameters:
##     alpha = 0.4426
##     gamma = 1e-04
##
##   Initial states:
##     l = 1173.6676
##     s = 296.9907 -34.3415 -457.6839 -271.7606 63.9589 172.9509
##            229.8854
##
##   sigma:  232.0085
##
##      AIC     AICc      BIC
## 5519.446 5520.136 5557.437
```

.

```r
fc_hyn <- forecast(fit_hyn, h = length(test_hyn))
accuracy(fc_hyn, test_hyn)
##                      ME     RMSE      MAE       MPE     MAPE      MASE
## Training set   3.727848 228.8229 164.1102 -2.026679 13.86475 0.7404020
## Test set     -73.167844 231.3494 180.9392 -8.044075 13.09378 0.8163279
##                   ACF1 Theil's U
## Training set 0.1874059        NA
## Test set     0.3712518 0.5878683
```

Figure 19 . test data , . 80% 95% , 80% , 95% .

```r
autoplot(fc_hyn, include = 0) +
  autolayer(test_hyn, color = "red", size = .8) +
  labs(x = NULL, y = NULL)
```

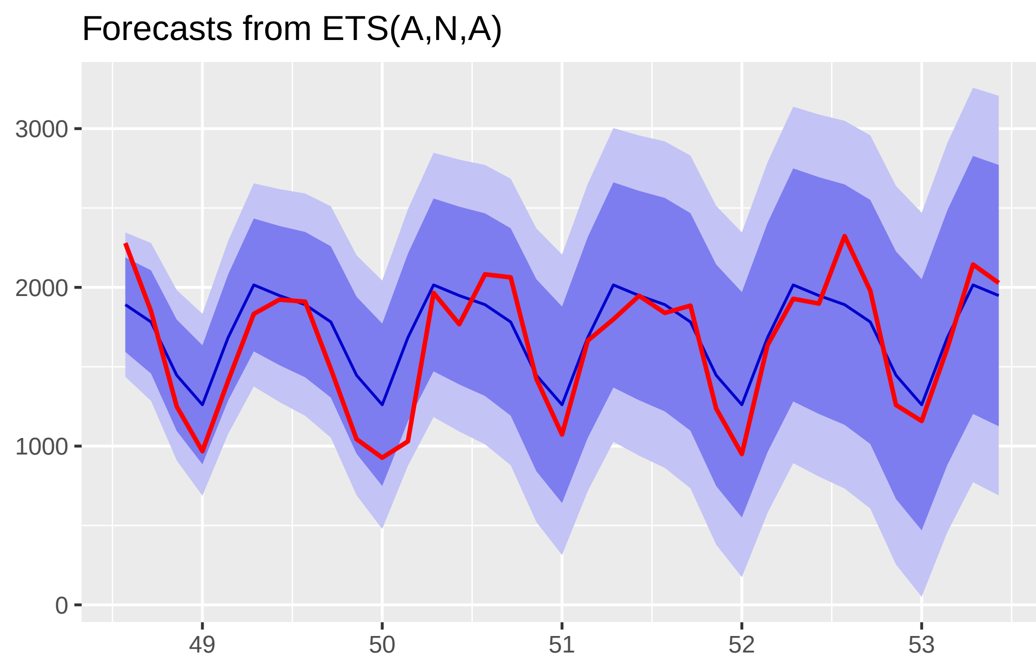


Figure 19: `hynsight`

1. ETS , .

- `fma::chicken`
- `fma::ibmclose`

2. ETS . Test data 2 , .
`https://raw.githubusercontent.com/yjyjpark/TS-with-R/main/Data/` .

- : `Seoul_temp.csv`
- : `Suwon_temp.csv`
- : `Baek_pm10.csv`
- : `Seoul_pm10.csv`
- : `Suwon_pm10.csv`

3. `Won_USD.csv` . Test data 2 .

- ETS .

- ETS .