

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)
```

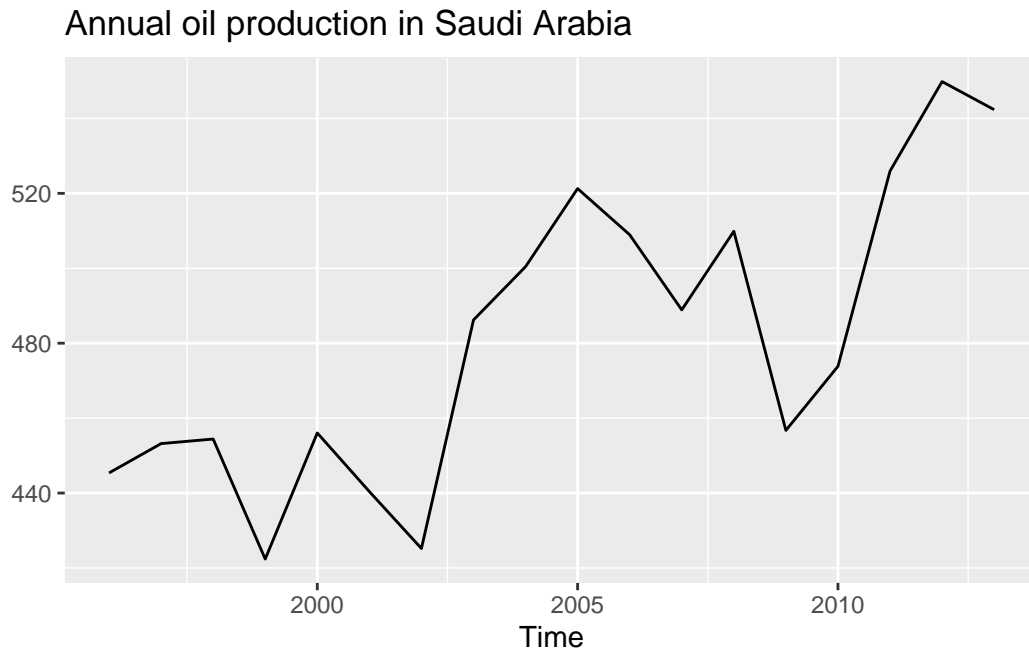


Figure 1: 1996 Saudi Arabia

```
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)
```

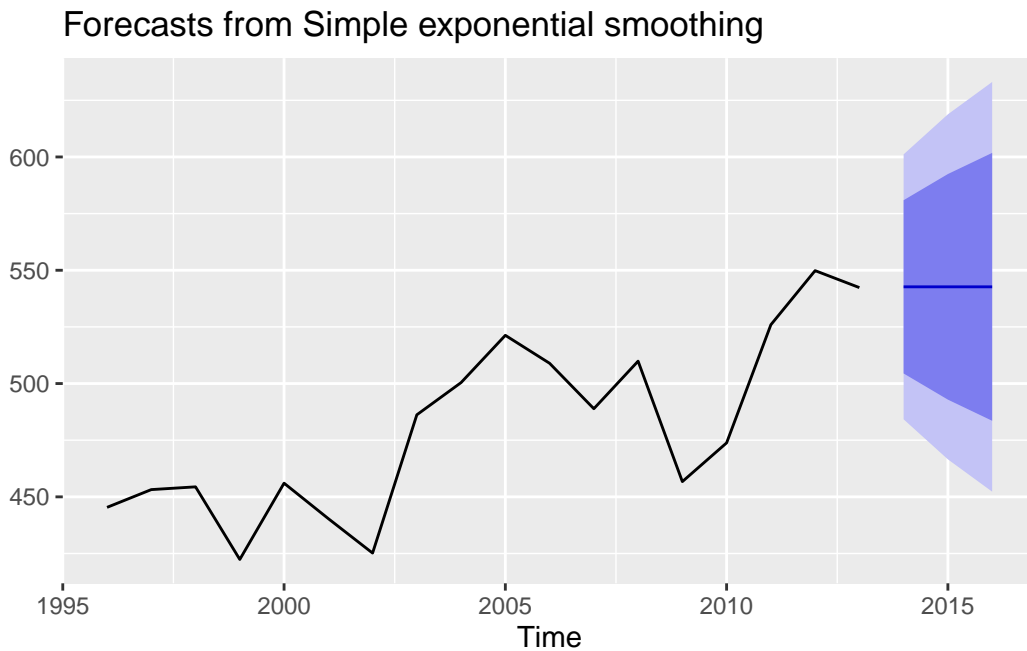


Figure 2: 1996 Saudi Arabia 2014

level , h . 80% , 95%

- Trend method : `fpp2::ausair`

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

Figure 3

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

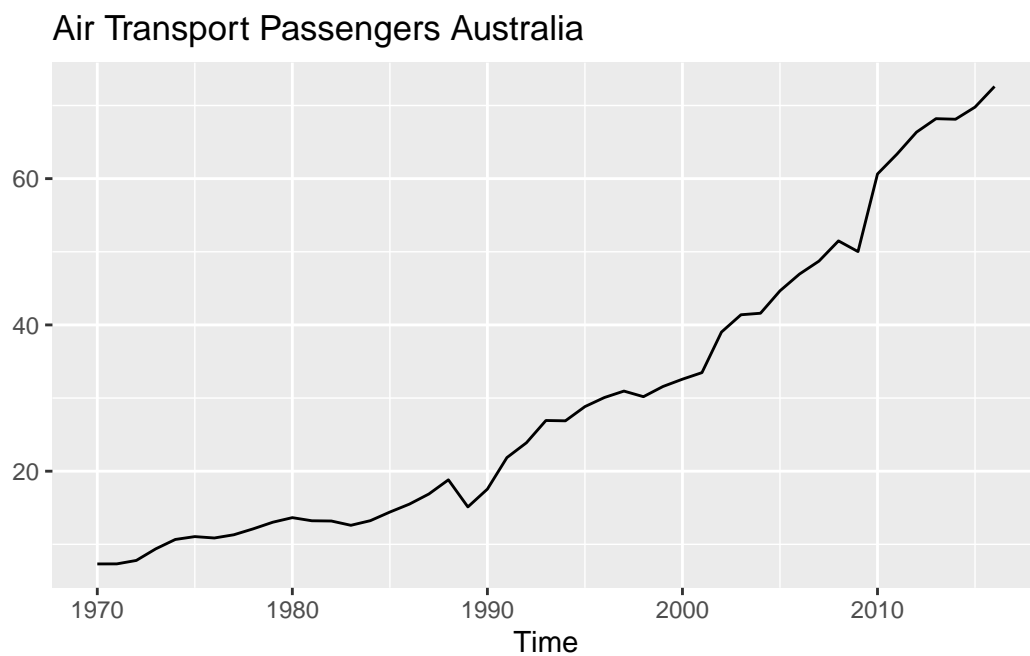


Figure 3: 1970 2016

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

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

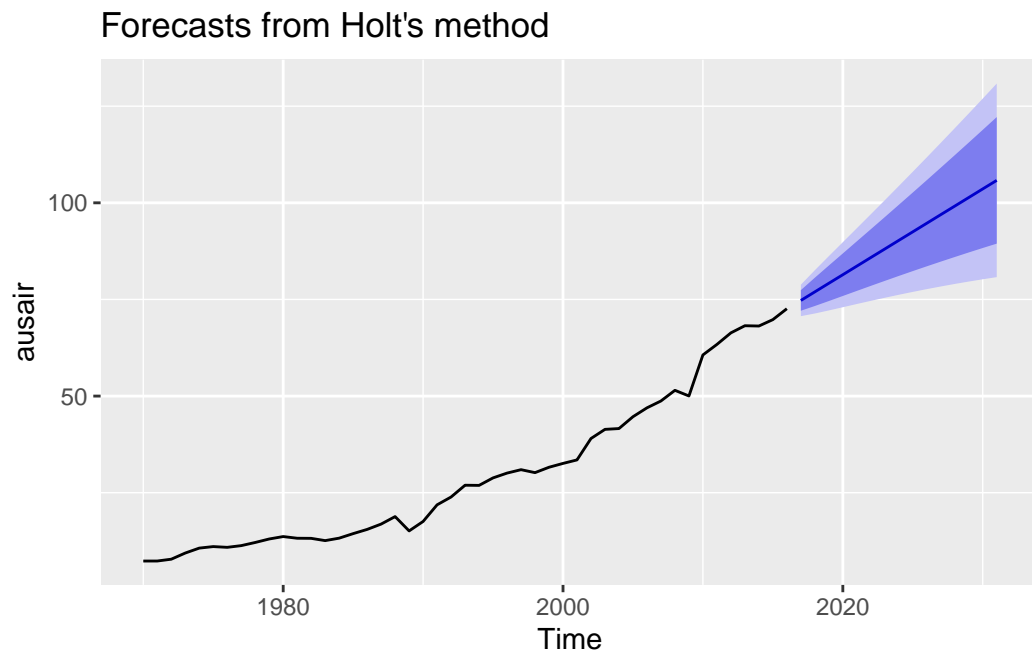


Figure 4: `ausair` Holt's linear trend method

Damped Holt's trend

. Figure 5 .

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

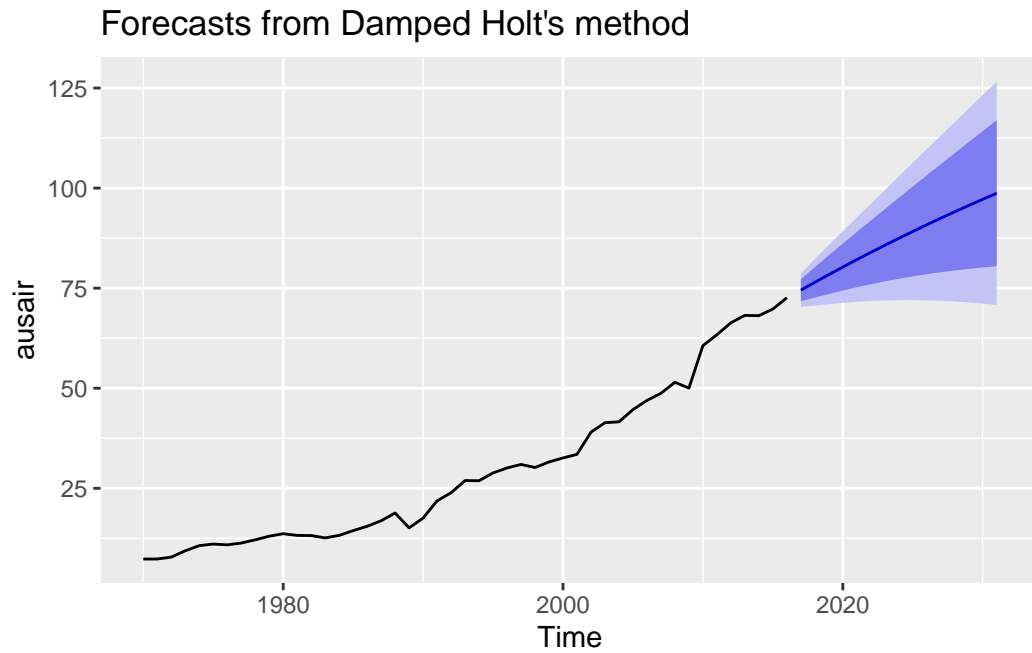


Figure 5: `ausair` damped Holt's trend method

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")
```

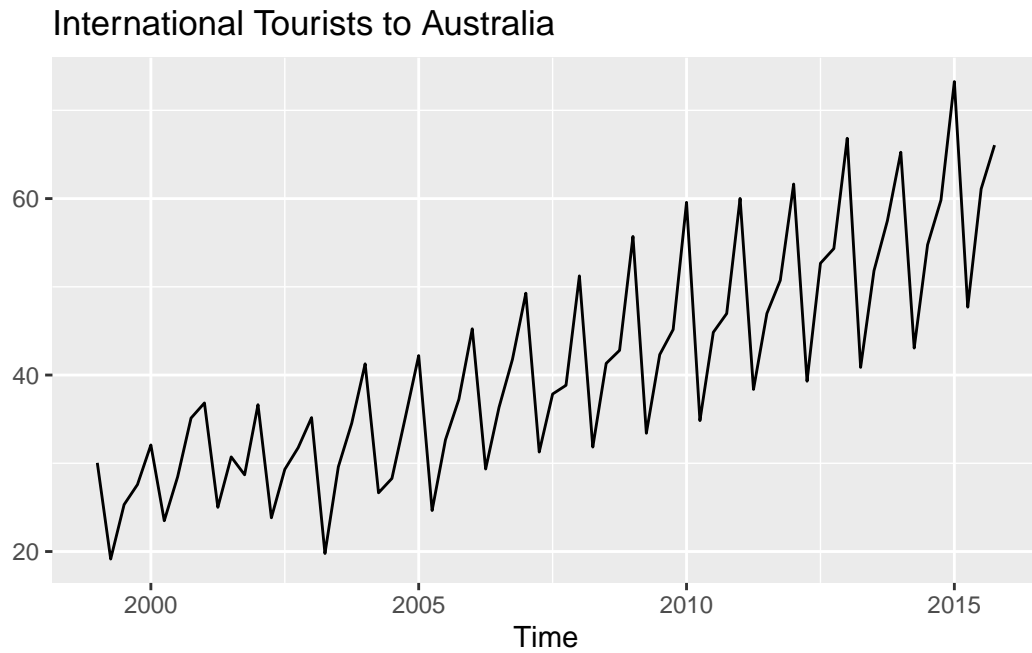


Figure 6: 199 2015

Holt-Winters' seasonal

Figure 7

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

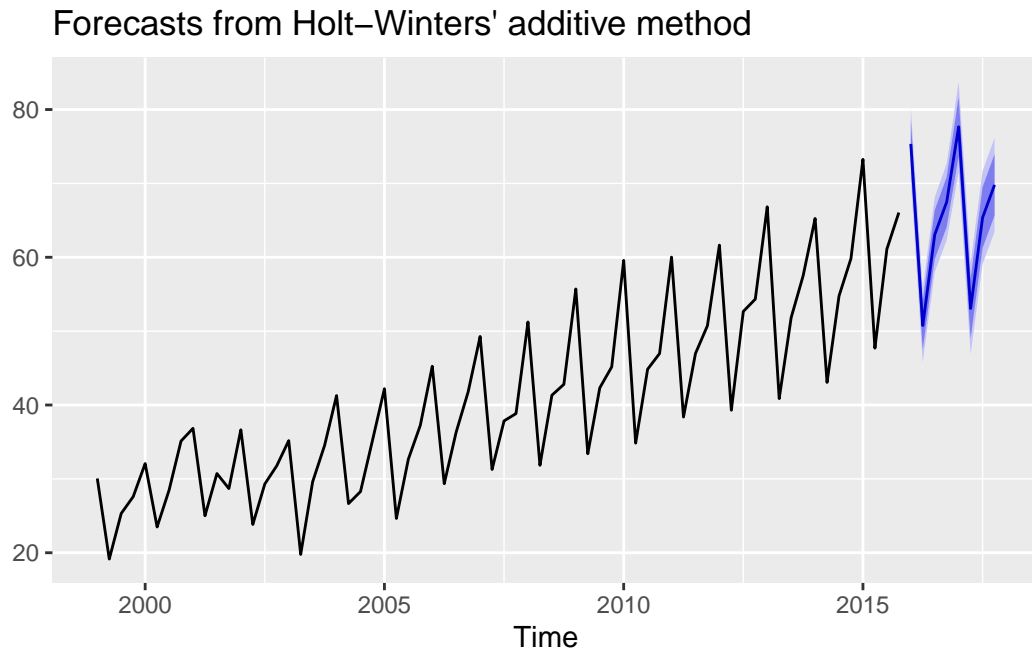


Figure 7: `austourists` Holt-Winters' additive seasonal method

Figure 8 .

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

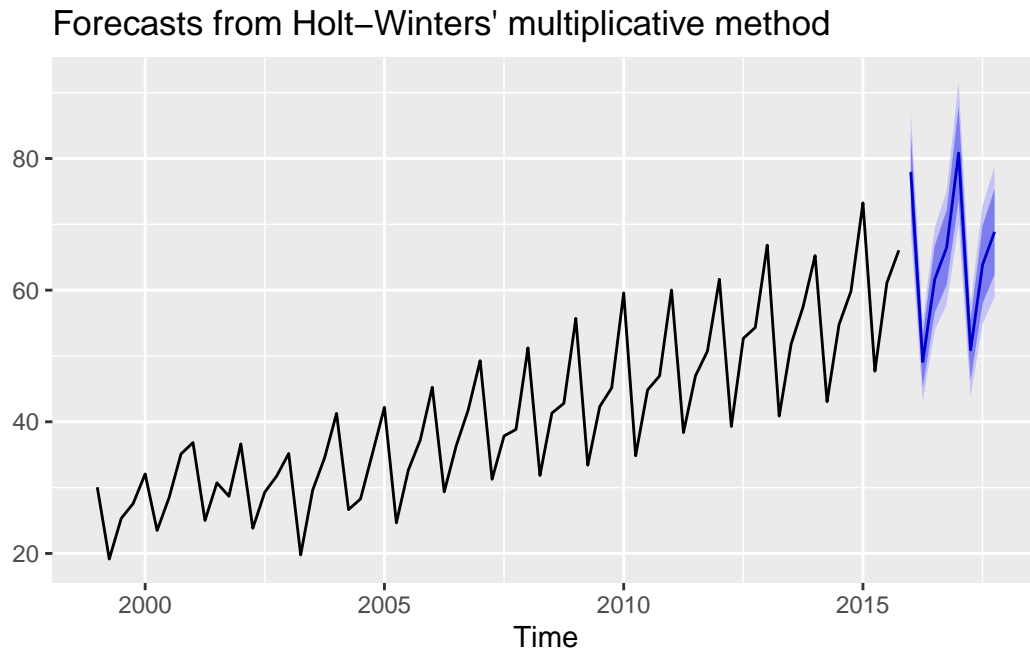



Figure 8: `austourists` Holt-Winters' multiplicative seasonal method

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")
```

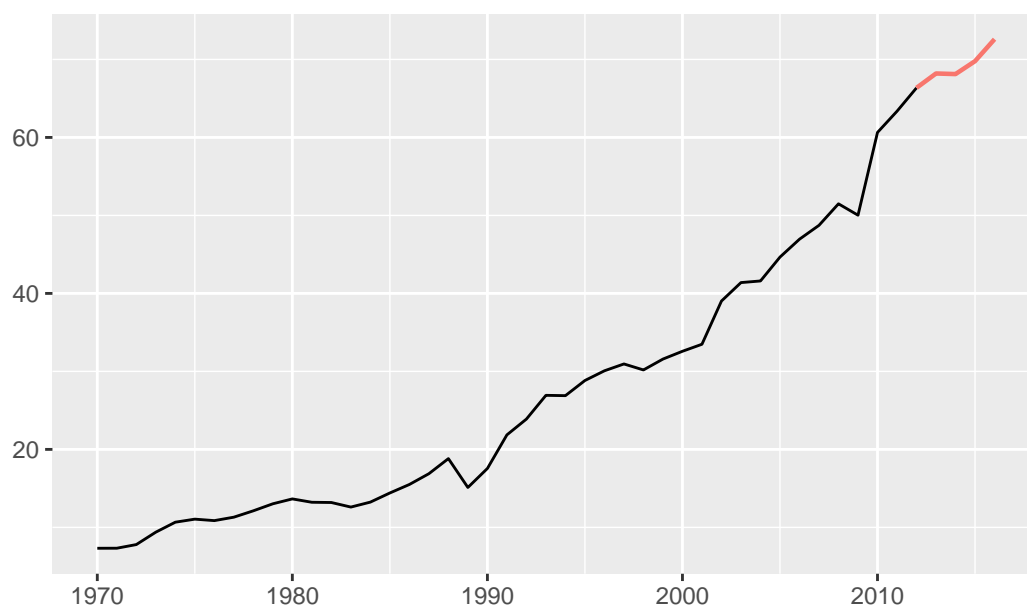


Figure 9: ausair

```
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 .

```
autoplot(fit_air)
```

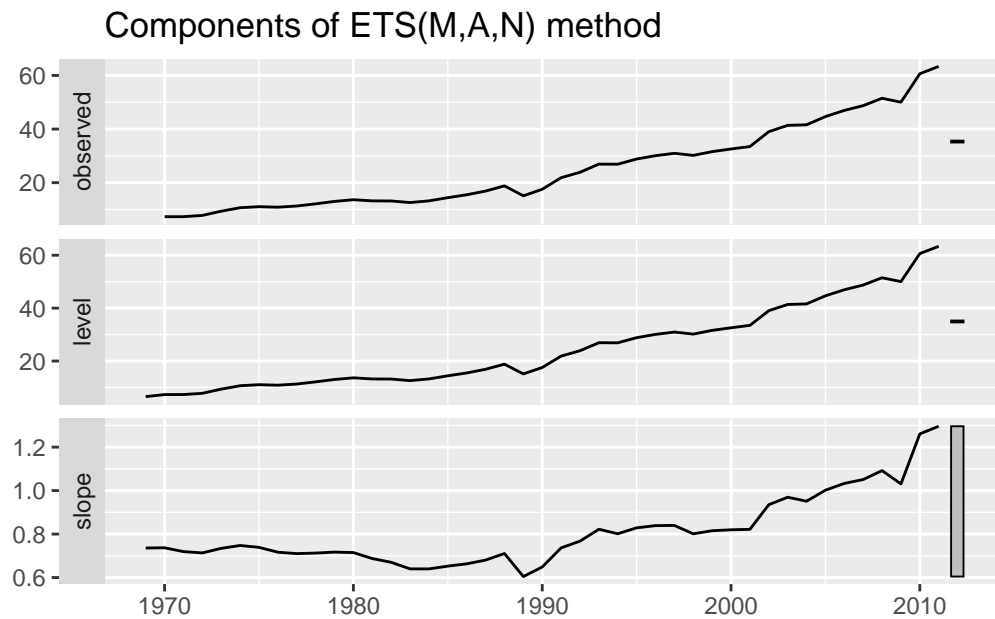
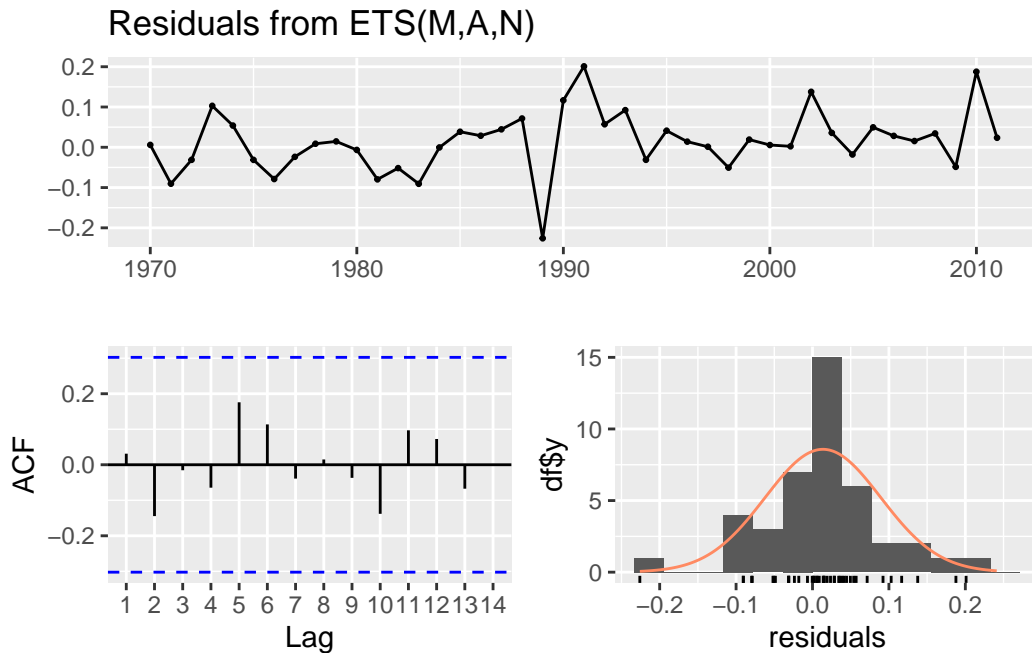


Figure 10: ETS

```
checkresiduals()
```

```
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
```

```
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
```

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

```
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
```

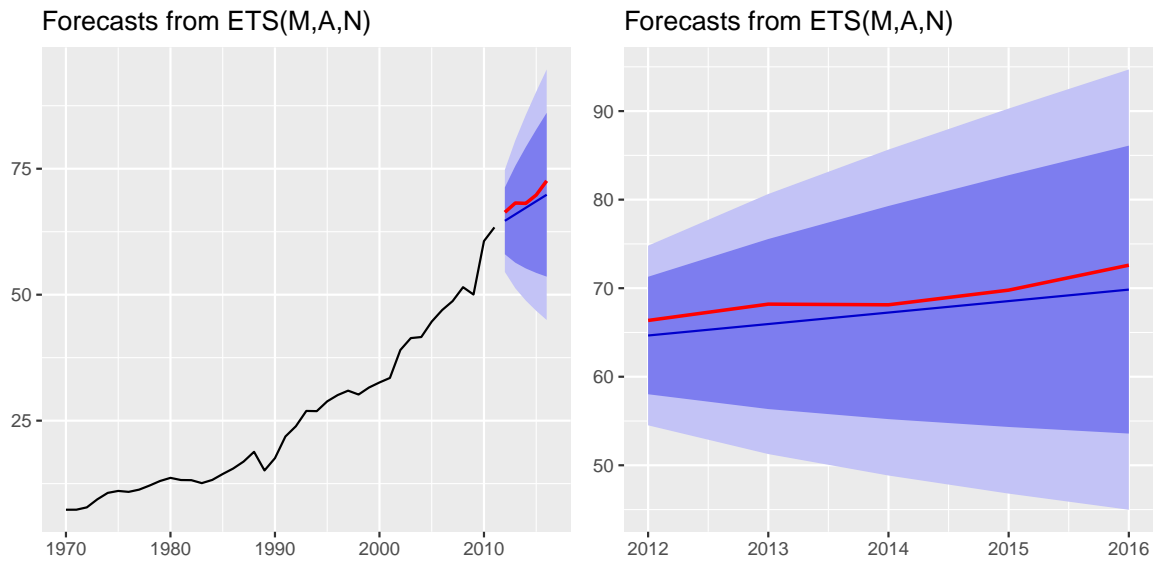


Figure 11: fpp2::ausair ETS

- 2: 1999 2015 (fpp2::austourists)

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

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

Figure 12 . Test data . , .

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

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

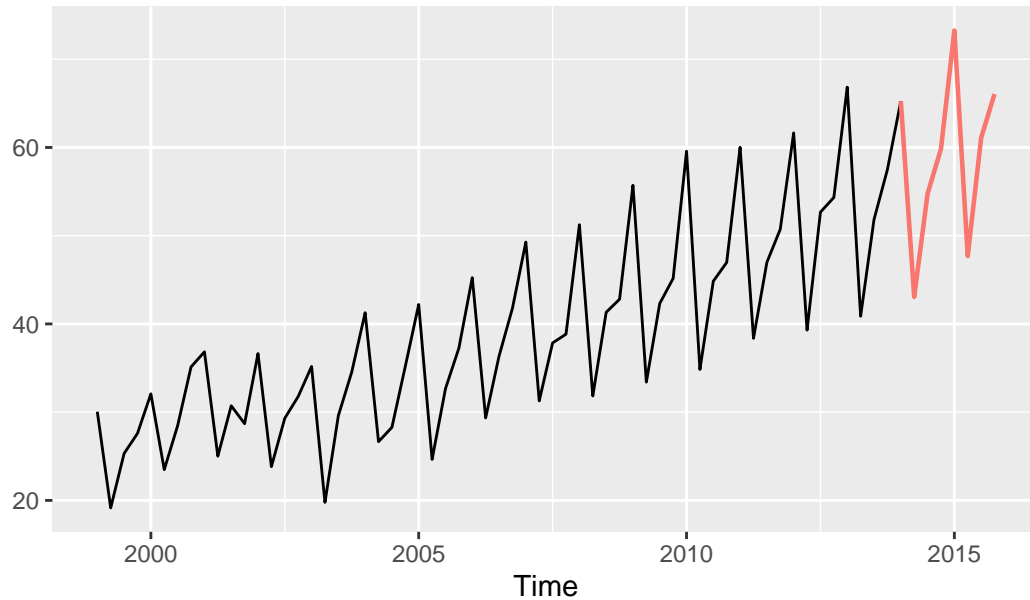


Figure 12: austourists

```
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
```

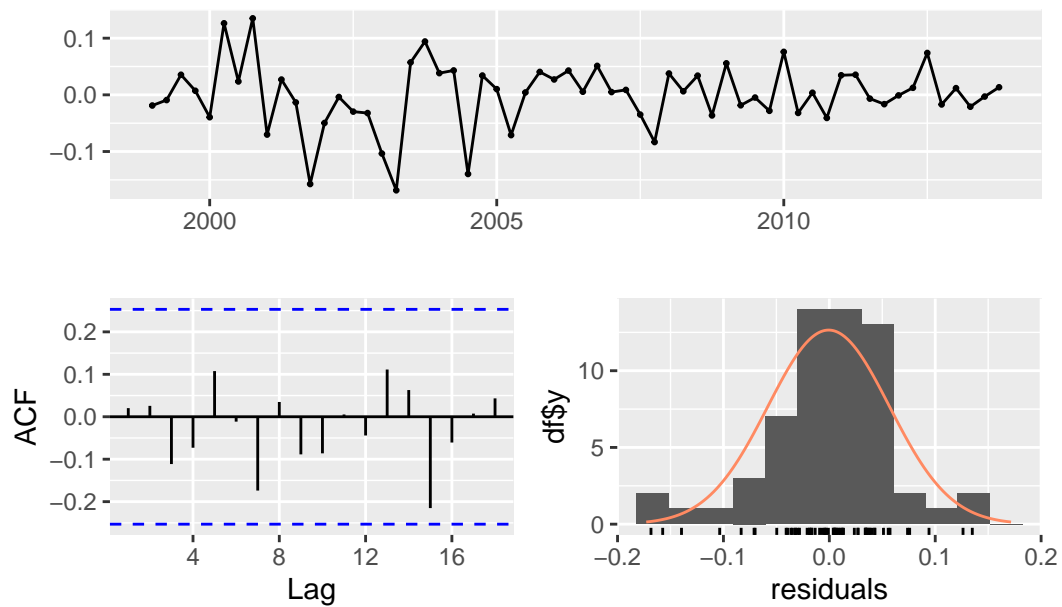
```
##      b = 0.5179
##      s = 1.0367 0.9578 0.7697 1.2358
##
##      sigma: 0.0612
##
##      AIC      AICc      BIC
## 353.3882 356.9882 372.2373
```

```
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)
```

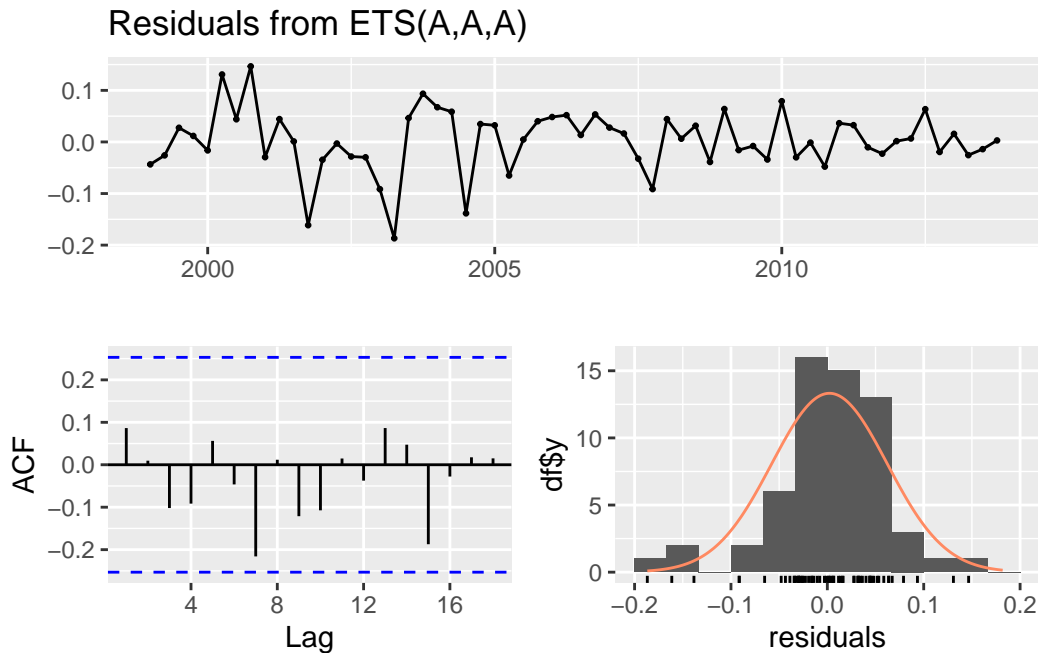
Residuals from ETS(M,A,M)



```
##
##  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
autolayer() PI = FALSE
```

Figure 13

```
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
```

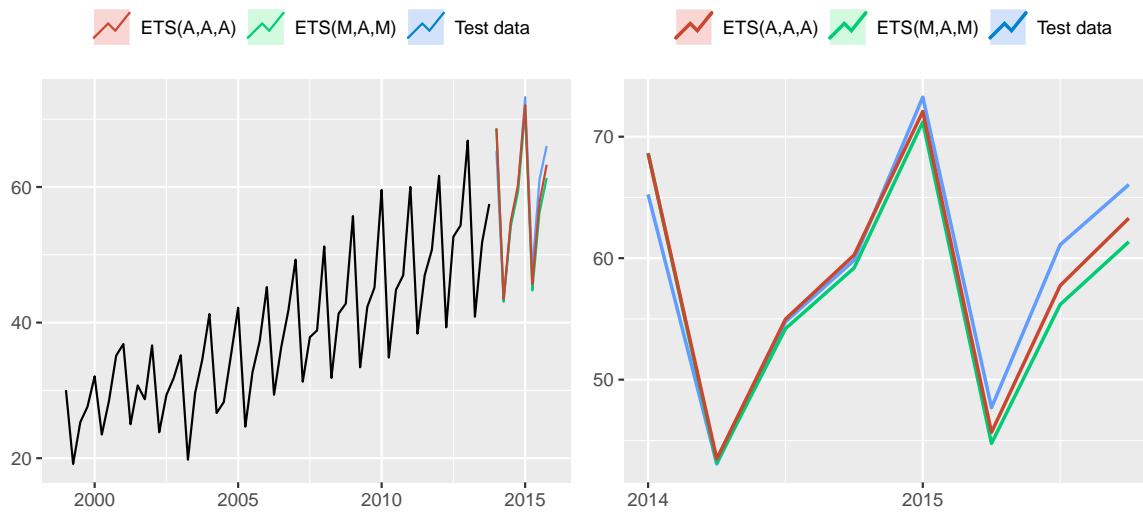


Figure 13: austourists

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
```

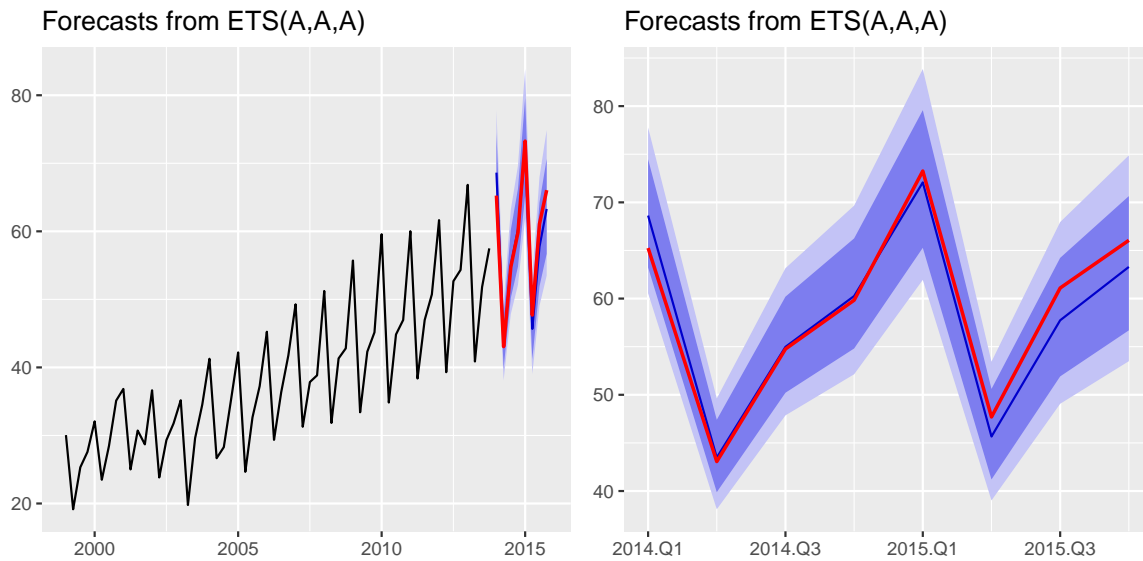


Figure 14: austourists

- 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)
```

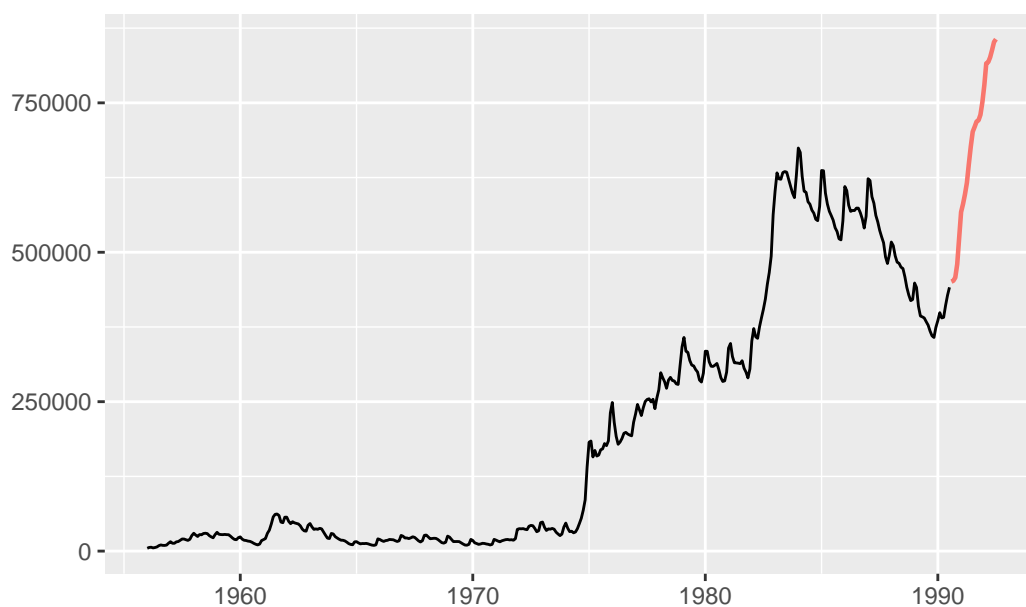


Figure 15: dole

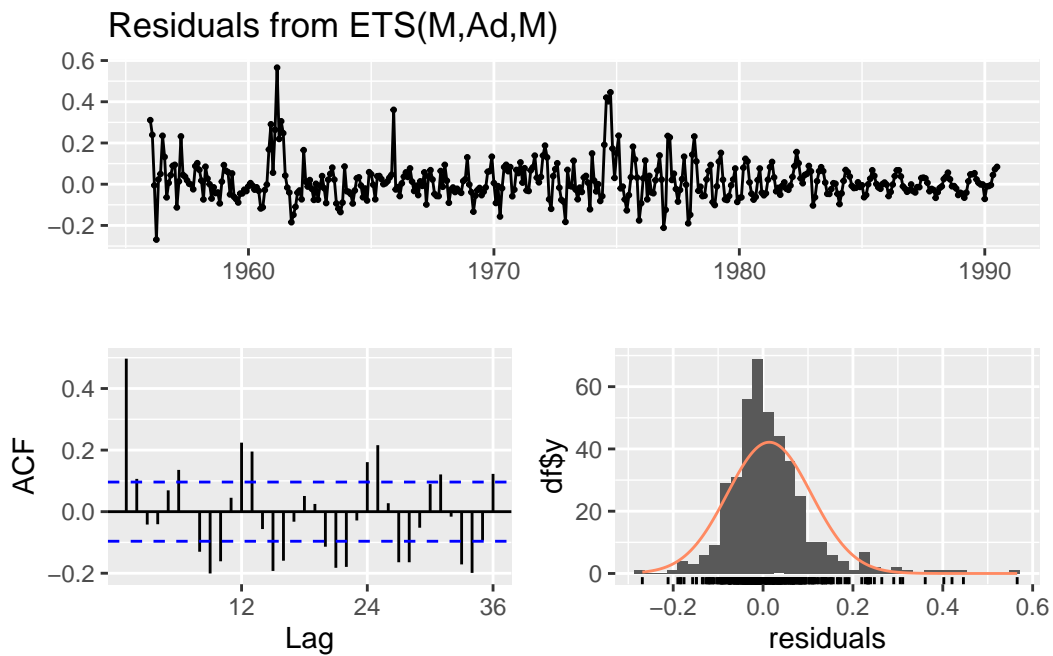
ETS

```
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) , .

```
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
```

.

```
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 .

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

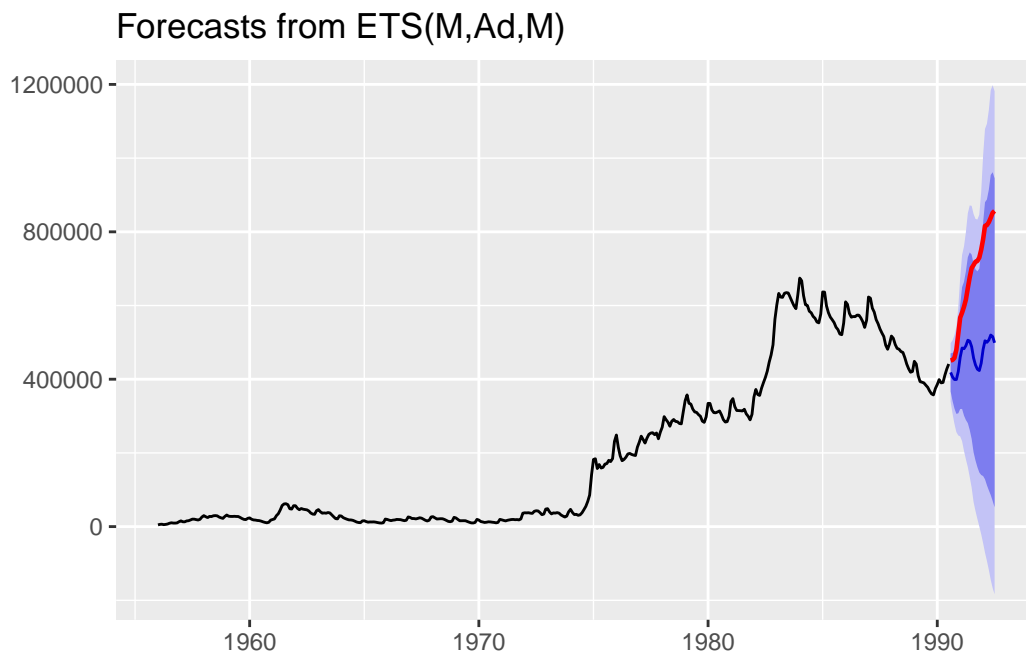


Figure 16: dole

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

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

training data 1 . .

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

```
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) .

```
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
```

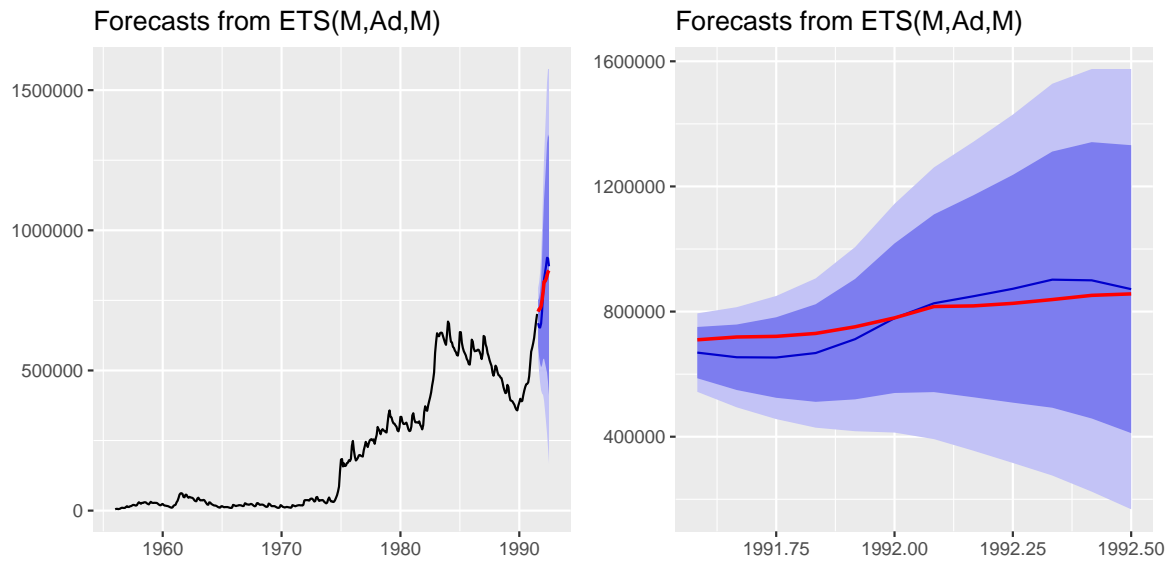



Figure 17: dole

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

hyndsight 2014 4 30 1 Hyndman

Figure 18

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

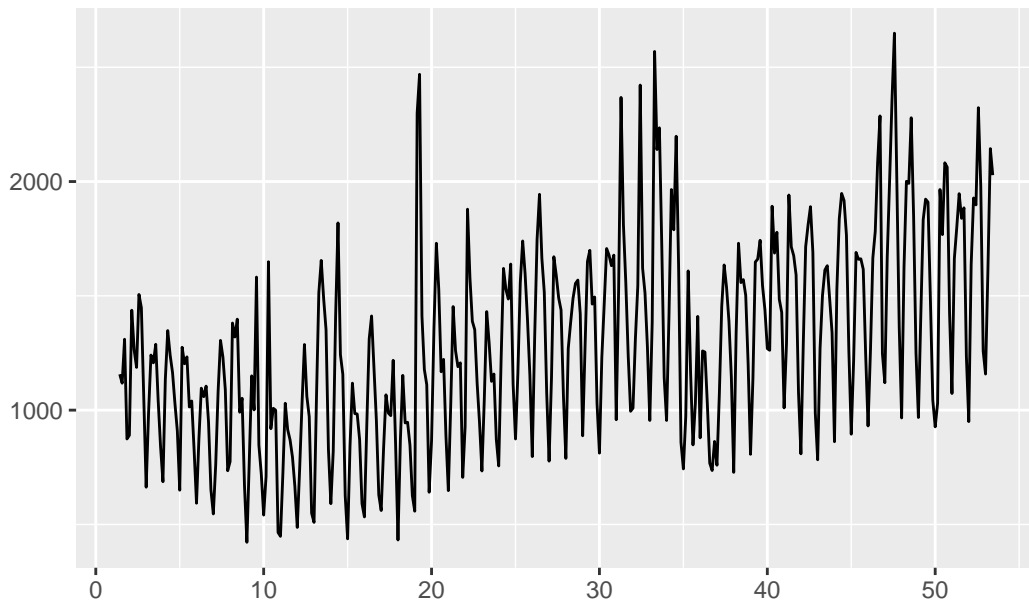


Figure 18: hyndsight

$m = 7$. 2014 4 30 .

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

```
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 .

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

ETS . , .

```

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

```

```

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% .

```

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

```

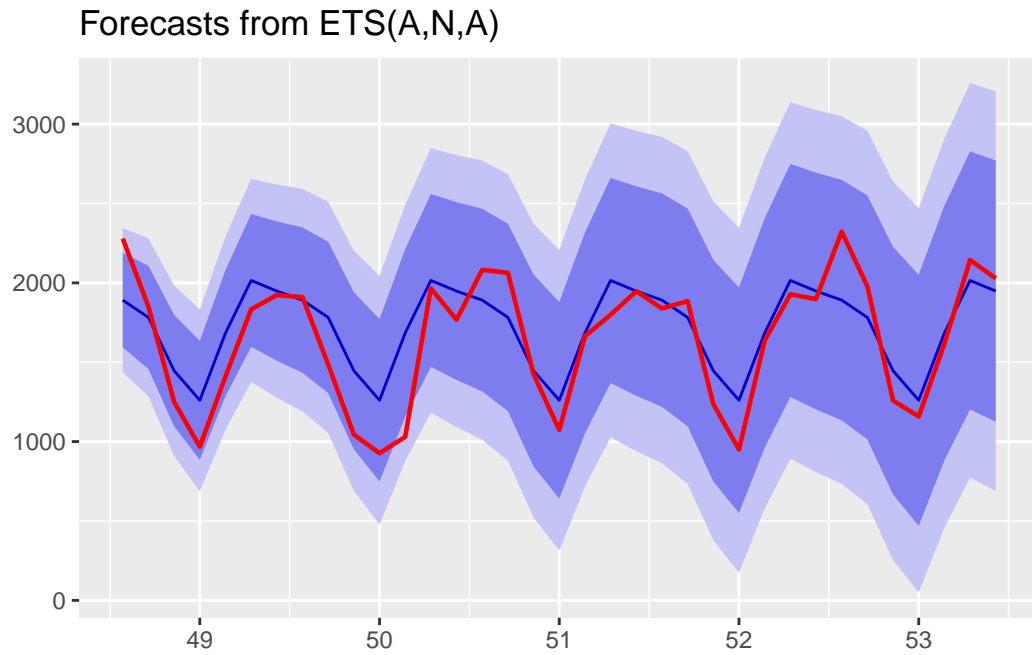


Figure 19: hynsight

1. ETS , .
 - fma::chicken
 - fma::ibmclose
2. Seoul_temp.xlsx Suwon_temp.xlsx , https://raw.githubusercontent.com/yjyjp/TS-with-R/main/Data/Seoul_temp.xlsx ,
 . ETS . Test data 2 . .
3. Baek_pm10.xlsx Seoul_pm10.xlsx, Suwon_pm10.xlsx , ,
https://raw.githubusercontent.com/yjyjpark/TS-with-R/main/Data/Baek_pm10.xlsx ,
 ETS . Test data 2 . .