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Selection for the best ETS (error, trend, seasonal) model to forecast weather in the Aceh Besar District

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Abstract. Weather is a phenomenon that occurs in certain areas that indicate a change in natural activity. Weather can be predicted using data in previous periods over a period. The purpose of this study is to get the best ETS model to predict the weather in Aceh Besar. The ETS model is a time series univariate forecasting method; its use focuses on trend and seasonal components. The data used are air temperature, dew point, sea level pressure, station pressure, visibility, wind speed, and sea surface temperature from January 2006 to December 2016. Based on AIC, AICc and BIC the smallest values obtained the conclusion that the ETS (M, N, A) is used to predict air temperature, and sea surface temperature, ETS (A, N, A) is used to predict dew point, sea level pressure and station pressure, ETS (A, A, N) is used to predict visibility, and ETS (A, N, N) is used to predict wind speed.

1. Introduction
Weather and climate is component of the natural ecosystem that affects the life processes of human, animal and even plants. Based on data collected by the Intergovernmental Panel on Climate Change (IPCC), the earth temperature has increased by 0.8 °C measured from the beginning of the 20th and estimated at the end of the 21st the earth's temperature will be increased to 2.4°– 6.4 °C [1]. Weather can be predicted using data in previous periods with studying trend data. Forecasting for time series data can be done with a time series univariate and can also be multivariate.

In this study, ETS (Error, Trend, Seasonal) was chosen as the method to be used to forecast weather elements (air temperature, visibility, wind speed, dew point, station pressure, sea level temperature and sea surface temperature). The purpose of this research is to get the best ETS model for every weather element in Aceh Besar.

2. Literature Review

2.1. Weather Elements
Weather is a physical phenomenon from the atmosphere at the place and at a shorter time. While, the climate is the average of the weather on a year that investigation in a long time (minimum 30 years) and covers a large area [2].

The air temperature is the degree of heat of the molecular activity in the atmosphere, expressed in Celcius (C), Reamur (R) and Fahrenheit (F) [3]. Air pressure is the power to drive air masses within each area, expressed in Celcius (C), Reamur (R) and Fahrenheit (F) [4]. Wind speed is the speed of air that moves horizontally or vertically at 2m above ground level, expressed in knots [3]. Visibility is the
ability to see an object horizontally and expressed in miles [5]. Sea surface temperature is one of the parameters that determine the quality of the waters, expressed in Celcius (C). SPL is an important factor influencing the dynamics of regional climate and global climate [6].

2.2. ETS (Error, Trend, Seasonal)

ETS (Error, Trend, Seasonal) method is an approach method for forecasting time series univariate. This ETS model focuses on trend and seasonal components [7]. The flexibility of the ETS model lies in its ability to trend and seasonal components of different traits.

The components are as follows:

| Trend Component | Seasonal Component |
|-----------------|--------------------|
|                | N (None) A (Additive) M (Multiplicative) |
| N (None)       | NN NA NM           |
| A (Additive)   | AN AA AM           |
| Ad (Additive Damped) | AdN AdA AdM       |
| M (Multiplicative) | MN MA MM       |
| Md (Multiplicative Damped) | MdN MdA MdM |

The combination of ETS models obtained from the above components:

| Model                 | Model               | Model               |
|-----------------------|---------------------|---------------------|
| ETS (M, M, N)         | ETS (A, M, A)       | ETS (M, N, M)       |
| ETS (M, A, N)         | ETS (A, Md, N)      | ETS (M, N, A)       |
| ETS (M, A, M)         | ETS (A, Md, M)      | ETS (M, N, N)       |
| ETS (A, M, N)         | ETS (A, N, A)       | ETS (M, A, A)       |
| ETS (A, N, N)         | ETS (M, Ad, M)      | ETS (A, Ad, M)      |
| ETS (A, A, M)         | ETS (M, Ad, N)      | ETS (M, M, A)       |
| ETS (M, M, M)         | ETS (M, Md, M)      | ETS (A, A, A)       |
| ETS (A, N, M)         | ETS (A, Ad, N)      | ETS (A, Ad, A)      |
| ETS (A, A, N)         | ETS (M, Md, A)      | ETS (M, Ad, A)      |
| ETS (A, M, M)         | ETS (M, Md, N)      | ETS (A, Md, A)      |

From the ETS model above, there are 15 models with additive errors and 15 models with multiplicative errors. In time series analysis it is possible to have some models that meet the assumptions. Related to that, to determine the best model of 30 ETS model can be used several criteria such as Akaike's Information Criterion (AIC), Akaike's Information Criterion correction (AICc) and Bayesian Information Criterion (BIC) [9].

Akaike's Information Criterion (AIC) can be calculated using the following equation:

$$AIC = -2 \left( \frac{LL}{T} \right) + \frac{2tp}{T}$$

with:

- $AIC$ = Akaike Information Criterion
- $LL$ = log likelihood
- $tp$ = Total Parameters
- $T$ = Number of observations
Akaike’s Information Criterion correction (AICc) can be calculated using the following equation:

$$AIC_c = AIC + \frac{2k(k+1)}{n-k-1}$$

with $\frac{2k(k+1)}{n-k-1}$ is bias correction.

Bayesian Information Criterion (BIC) can be calculated using the following equation:

$$BIC = -2LL + k \ln (n)$$

with:
- $LL$ = log likelihood
- $k$ = Estimation of parameter model
- $n$ = Number of observations

3. Research Methods

3.1. Data

This study uses data obtained from the website www.noaa.gov. The data is a monthly data of weather elements in Aceh Besar (Satellite Station Blang Bintang). The data used were 132 observations from January 2006-December 2016 for each variable, but the SST variable used data from September 2006 to August 2016 with missing data from January 2013-April 2015. Data analysis was done with software R 3.0.3. Here are the variables:

| No | Variables               | Unit |
|----|-------------------------|------|
| 1  | temp (Air Temperature)  | °C   |
| 2  | dewp (Dew Point)        | °C   |
| 3  | slp (Sea Level Pressure)| mb   |
| 4  | stp (Station Pressure)  | mb   |
| 5  | visib (Visibility)      | miles|
| 6  | wdsp (Wind Speed)       | knot |
| 7  | sst (Sea Surface Temperature) | °C |

3.2. Analytical Procedures

The data analysis procedure in this study consists of:
1. Data of weather elements (air temperature, visibility, wind speed, dew point, station pressure, sea surface pressure and sea surface temperature) are inputted into software R 3.0.3.
2. To descriptive analysis by looking at the characteristics of data through data summary.
3. To inferencing analysis using 30 combinations of ETS models for each weather element.
4. Choose the best ETS model based on the smallest AIC, AICc and BIC values for each weather element.
4. Results and Discussion

4.1. Descriptive analysis

To know the characteristics data of weather elements can be seen in the following table:

| Variable          | Characteristics | Value | Variable          | Characteristics | Value |
|-------------------|-----------------|-------|-------------------|-----------------|-------|
| **Air temperature** | Maximum         | 29,28 | Minimum           | Maximum         | 6,25  |
|                   | Minimum         | 25,72 | Minimum           | Minimum         | 4,00  |
|                   | Mean            | 27,29 | Mean              | 5,86            |
|                   | Median          | 27,31 | Median            | 6,00            |
|                   | Quartile 1      | 26,72 | Quartile 1        | 5,75            |
|                   | Quartile 3      | 27,81 | Quartile 3        | 6,00            |
|                   | Maximum         | 24,59 | Maximum           | 8,00            |
|                   | Minimum         | 21,01 | Minimum           | 0,67            |
|                   | Mean            | 22,87 | Mean              | 3,76            |
|                   | Median          | 22,90 | Median            | 3,75            |
|                   | Quartile 1      | 22,24 | Quartile 1        | 3,19            |
|                   | Quartile 3      | 23,50 | Quartile 3        | 4,30            |
|                   | Maximum         | 1012  | Maximum           | 30,71           |
|                   | Minimum         | 1007  | Minimum           | 28,26           |
|                   | Mean            | 1010  | Mean              | 29,25           |
|                   | Median          | 1010  | Median            | 29,22           |
|                   | Quartile 1      | 1009  | Quartile 1        | 29,00           |
|                   | Quartile 3      | 1010  | Quartile 3        | 29,33           |
|                   | Maximum         | 1009  | Data lost         | 34              |
|                   | Minimum         | 1005  |                   |                 |
|                   | Mean            | 1007  |                   |                 |
|                   | Median          | 1007  |                   |                 |
|                   | Quartile 1      | 1007  |                   |                 |
|                   | Quartile 3      | 1008  |                   |                 |

Based on Table 4, we can know the characteristics of weather elements in Aceh Besar district 2006-2016 as follows:

1. Water temperature obtained an average of 27,29 °C with a minimum temperature of 25,72 °C and a maximum temperature of 29,28 °C. The water temperature obtained the mean, median and quartile three which ranges from 27 °C.
2. Dewpoint, obtained an average of 22,87 °C with a minimum temperature of 21,01 °C and a maximum temperature of 24,59 °C. At dewpoint the mean and median values at the same temperature that is 22 °C.
3. Sea level pressure obtained the average of 1010mb with the lowest pressure of 1007mb and the highest pressure is 1012mb. The sea level pressure obtains the mean, median and quartile three values are precisely the same value of 1010mb.
4. Station pressure, obtained an average of 1007mb with the lowest pressure of 1005mb and the highest pressure is 1009mb. Also the station pressure also obtained the same value for the mean, median and quartile 1 is equal to 1007mb.
5. Visibility obtained an average of 5,86 miles with the closest distance of 4,00 miles and the farthest distance of 6,25 miles. On visibility also obtained the same value for median and quartile three that is equal to 6,00 miles.
6. Wind speed obtained an average of 3.76 knots with a late speed of 0.67 knots and the fastest speed of 8.00 knots. Besides, wind speed has a more significant range value when compared with other weather elements that are equal to 7.

7. Sea surface temperature, obtained an average of 29.25 °C with a minimum temperature of 28.26 °C and a maximum temperature of 30.71 °C. Also, the correct values of the mean, median, quartile 1 and quartile 3 are in the same value of 29 °C. As well as on variable sea surface temperature there are lost data as much as 34 periods.

4.2 Inference Analysis

Inference analyzes were performed using 30 combinations of ETS models, and only a few model can be used to predict the weather elements. From the model used the best model is chosen by looking at the smallest AIC, AICc and BIC values.

Here are the combinations ETS model for air temperature in Aceh Besar in 2006-2016:

| Model ETS | AIC  | AICc  | BIC   |
|-----------|------|-------|-------|
| M, M, N  | 500.5896 | 500.9046 | 512.1208 |
| M, A, N  | 500.7238 | 501.0387 | 512.2550 |
| M, Ad, M | 439.5239 | 444.8978 | 488.5370 |
| A, N, N  | 497.6485 | 497.7415 | 503.4141 |
| M, Md, M | 442.1614 | 477.5299 | 491.1691 |
| A, A, N  | 501.9201 | 502.2351 | 513.4513 |
| A, N, A  | 433.8487 | 437.4385 | 474.2080 |
| M, N, M  | 438.6933 | 442.2830 | 497.0525 |
| M, N, A  | 432.5406 | 436.1304 | 472.8998 |
| M, N, N  | 496.5606 | 496.6536 | 502.3262 |
| M, Ad, A | 437.5158 | 443.1233 | 486.7625 |
| A, A, A  | 439.5158 | 444.2462 | 485.6406 |

From the Table 5 obtained the best model is ETS (M, N, A) to predict water temperature in Aceh Besar in 2017-2018 with AIC of 432.5406, AICc of 436.1304 and BIC of 472.8998.

Here is the combinations ETS model for dew point in Aceh Besar in 2006-2016:

| Model ETS | AIC  | AICc  | BIC   |
|-----------|------|-------|-------|
| M, Md, N  | 547.9749 | 548.4511 | 562.3889 |
| M, A, N  | 545.5890 | 545.9039 | 557.1202 |
| M, Ad, M | 476.1028 | 481.4712 | 525.1104 |
| A, N, N  | 541.3037 | 541.4003 | 547.0729 |
| M, Md, M | 475.3339 | 480.7023 | 524.3415 |
| A, A, N  | 545.3121 | 545.6270 | 556.8433 |
| A, N, A  | 468.0783 | 471.6681 | 508.4376 |
| M, N, M  | 470.4469 | 474.0366 | 510.8061 |
| M, N, A  | 468.2307 | 471.8205 | 508.5899 |
| M, N, N  | 541.7574 | 541.8504 | 547.5230 |
| M, A, A  | 475.8386 | 480.5691 | 521.9635 |
| A, A, A  | 473.5571 | 478.2876 | 519.6820 |

From the Table 6 obtained the best model is ETS (A, N, A) to predict dew point in Aceh Besar in 2017-2018 with AIC of 468.0783, AICc of 471.6681 and BIC of 508.4376.

Here is the combinations ETS model for sea level pressure in Aceh Besar in 2006-2016:
Table 7. ETS model sea level pressure

| Model ETS  | AIC    | AICc   | BIC    |
|------------|--------|--------|--------|
| M,M,N      | 655,1631 | 655,4781 | 666,6943 |
| M,A,N      | 654,9047 | 655,2196 | 666,4359 |
| M,Ad,M     | 595,0740 | 600,4424 | 644,0816 |
| A,N,N      | 651,5644 | 651,6574 | 657,3300 |
| M,M,M      | 491,5557 | 496,2861 | 537,6805 |
| A,A,N      | 565,4636 | 565,7786 | 576,9948 |
| A,N,A      | 484,7299 | 488,3196 | 525,0891 |
| M,M,N      | 485,2665 | 488,8563 | 525,6258 |
| M,N,A      | 485,1053 | 488,6951 | 525,4646 |
| M,N,N      | 561,3579 | 561,4509 | 567,1235 |
| M,Ad,A     | 492,3699 | 497,7383 | 541,3775 |
| A,A,A      | 492,4421 | 497,1725 | 538,5669 |

From the Table 7 obtained the best model is ETS (A, N, A) to predict sea level pressure in Aceh Besar in 2017-2018 with AIC of 484,7299, AICc of 488,3196 and BIC of 525,0891.

Here is the combinations ETS model for station pressure in Aceh Besar in 2006-2016:

Table 8. ETS model station pressure

| Model ETS  | AIC    | AICc   | BIC    |
|------------|--------|--------|--------|
| M,Md,N     | 565,7366 | 566,2128 | 580,1506 |
| M,A,N      | 563,7944 | 564,1094 | 575,3256 |
| M,A,M      | 489,2061 | 493,9365 | 535,3309 |
| A,N,N      | 559,8000 | 559,8930 | 565,5656 |
| M,M,M      | 489,5715 | 494,3019 | 535,6963 |
| A,A,N      | 563,8278 | 564,1428 | 575,3591 |
| A,N,A      | 481,8738 | 485,4636 | 522,2331 |
| M,N,M      | 482,4092 | 485,9990 | 522,7684 |
| M,N,A      | 481,9825 | 485,5722 | 522,3417 |
| M,N,N      | 559,7663 | 559,8593 | 565,5319 |
| M,AA,A     | 491,1983 | 495,9287 | 537,3231 |
| A,Ad,A     | 490,1326 | 495,5011 | 539,1403 |

From the Table 8 obtained the best model is ETS (A, N, A) to predict station pressure in Aceh Besar in 2017-2018 with AIC of 481,8738, AICc of 485,4636 and BIC of 522,2331.

Here is the combinations ETS model for visibility in Aceh Besar in 2006-2016:

Table 9. ETS model visibility

| Model ETS  | AIC    | AICc   | BIC    |
|------------|--------|--------|--------|
| M,M,N      | 341,4413 | 341,9175 | 355,8553 |
| M,A,N      | 335,6049 | 355,9199 | 347,1361 |
| M,Ad,M     | 350,9936 | 356,3621 | 400,0013 |
| A,N,N      | 334,6036 | 334,6966 | 340,3692 |
| M,M,M      | 361,7591 | 367,1275 | 410,7667 |
| A,A,N      | 333,5488 | 333,8638 | 345,0080 |
| A,N,A      | 341,3315 | 344,9213 | 381,6908 |
| M,N,M      | 381,2393 | 384,8291 | 421,5986 |
| M,N,A      | 339,6880 | 343,2777 | 380,0472 |
| M,N,N      | 335,0598 | 335,1528 | 340,8254 |
| M,AA,A     | 354,9128 | 360,2812 | 403,9205 |
| A,AA,A     | 344,7034 | 350,0718 | 393,7110 |
From the Table 9 obtained the best model is ETS (A, A, N) to predict visibility in Aceh Besar in 2017-2018 with AIC of 333,5488, AICc of 333,8638 and BIC of 3345,0800.

Here is the combinations ETS model for wind speed in Aceh Besar in 2006-2016:

**Table 10. ETS model wind speed**

| Model ETS | AIC       | AICc      | BIC       |
|-----------|-----------|-----------|-----------|
| M, M, N   | 677,9229  | 678,2379  | 689,4541  |
| M, A, N   | 674,6547  | 674,9697  | 686,1859  |
| M, A, M   | 687,8231  | 692,5517  | 733,9461  |
| A, N, N   | 666,8980  | 666,9910  | 672,6636  |
| M, M, M   | 682,0401  | 686,7705  | 728,1649  |
| A, Ad, N  | 667,8871  | 668,3633  | 682,3011  |
| A, N, A   | 676,8035  | 680,3932  | 717,1627  |
| M, N, M   | 678,1830  | 681,7727  | 718,5422  |
| M, N, A   | 675,8602  | 679,4500  | 716,2195  |
| M, N, N   | 673,3369  | 673,4299  | 679,1025  |
| M, Ad, A  | 682,6962  | 688,0647  | 731,7039  |
| A, A, A   | 683,3426  | 688,0730  | 729,4674  |

From the Table 10 obtained the best model is ETS (A, N, N) to predict wind speed in Aceh Besar in 2017-2018 with AIC of 666,8980, AICc of 666,9910 and BIC of 672,6636.

Here is the combinations ETS model for sea surface temperature in Aceh Besar in 2006-2016:

**Table 11. ETS model sea surface temperature**

| Model ETS | AIC       | AICc      | BIC       |
|-----------|-----------|-----------|-----------|
| M, Md, N  | 314,9518  | 315,5401  | 328,3625  |
| M, A, N   | 314,6889  | 315,0773  | 325,4175  |
| M, Ad, M  | 315,7892  | 322,5892  | 361,3854  |
| A, N, N   | 312,5315  | 312,6458  | 317,8957  |
| M, Md, M  | 314,4385  | 321,2385  | 360,0347  |
| A, A, N   | 316,3125  | 316,7009  | 327,0410  |
| A, N, A   | 305,2927  | 309,8088  | 312,8425  |
| M, N, M   | 304,9535  | 309,4696  | 312,5033  |
| M, N, A   | 304,7735  | 309,2896  | 312,3233  |
| M, N, N   | 311,0270  | 311,1413  | 316,3912  |
| M, A, A   | 312,8845  | 318,8626  | 355,7986  |
| A, A, A   | 313,6343  | 319,6123  | 356,5484  |

From the table 11 obtained the best model is ETS (M, N, A) to predict sea surface temperature in Aceh Besar in 2017-2018 with AIC of 304,7735 AICc of 309,2896 and BIC of 312,3233.

5. Conclusion and Suggestion

5.1. Conclusion

Based on AIC, AICc and BIC the smallest values obtained the judgment that the ETS (M, N, A) is used to predict air temperature and sea surface temperature, ETS (A, N, A) is used to predict dew point, sea level pressure and station pressure, ETS (A, A, N) is applied to predict visibility, and ETS (A, N, N) is used to predict wind speed.

5.2. Suggestion

This study focuses on trend and seasonal components for weather forecasting in Aceh Besar with variable air temperature, dew point, sea level pressure, station pressure, visibility, wind speed and sea
surface temperature, for the next researchers to forecast the elements weather with more attention to the error.

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