The skill assessment of ENSO prediction issued by JMA ensemble prediction system and CFSv2

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Abstract. Indonesian climate is strongly affected by El Niño-Southern Oscillation (ENSO) as one of climate-driven factor. ENSO prediction during the upcoming months or year is crucial for the government in order to design the further strategic policy. Besides producing its own ENSO prediction, BMKG also regularly releases the status and ENSO prediction collected from other climate centers, such as Japan Meteorological Agency (JMA) and National Oceanic and Atmospheric Administration (NOAA). However, the skill of these products is not well known yet. The aim of this study is to conduct a simple assessment on the skill of JMA Ensemble Prediction System (EPS) and NOAA Climate Forecast System version 2 (CFSv2) ENSO prediction using World Meteorological Organization (WMO) Standard Verification System for Long Range Forecast (SVM-LRF) method. Both ENSO prediction results also compared each other using Student's t-test. The ENSO predictions data were obtained from the ENSO JMA and ENSO NCEP forecast archive files, while observed Nino 3.4 were calculated from Centennial in situ Observation-Based Estimates (COBE) Sea Surface Temperature Anomaly (SSTA). Both ENSO prediction issued by JMA and NCEP has a good skill on 1 to 3 months lead time, indicated by high correlation coefficient and positive value of Mean Square Skill Score (MSSS). However, the skill of both skills significantly reduced for May-August target month. Further careful interpretation is needed for ENSO prediction issued on this mentioned period.

1. Introduction

In the recent decade, the national climate state has always been considered by Indonesian government to design the next strategic policy, particularly for the sector which is sensitive to the climate, such as agriculture, energy, etc. Indonesian climate is strongly affected by El Niño-Southern Oscillation (ENSO) [1], therefore information on the ENSO status during the upcoming months or year is very crucial. To support this government strategy, BMKG regularly releases the status and ENSO forecast. Besides producing its own ENSO prediction, BMKG also regularly releases the status and ENSO prediction collected from other climate centers, such as Japan Meteorological Agency (JMA) and National Oceanic and Atmospheric Administration (NOAA). However, the skill of these products is not well known yet. The ENSO forecast data released by JMA uses an atmosphere-ocean coupled general circulation model (CGCM), which consists of atmospheric general circulation model (AGCM) and the ocean general circulation model (OGCM). The atmospheric model has a resolution of TL159 (approximately 110 km grid spacing) with 60 levels up to 0.1 hPa and the horizontal resolution of the oceanic model is 1.0º longitude, 0.3-0.5º latitude with 52 levels and a bottom boundary layer [2]. This ocean model also improves coastal processes application by considering tide producing potential and inverse barometer.
effect of surface atmospheric pressure into the depth-integrated (barotropic) equations, vertically rescaled height coordinate, expanded nesting function, and expanded monitoring and sampling function [3]. CFSv2 ENSO forecast use global forecast system (GFS) atmospheric model and the modular ocean model (MOM4) oceanic model. CFSv2 has horizontal resolution of T126 (approximately −1°) with 64 levels vertical resolution, 24 ensemble members each month and has 9 months maximum forecast lead time [4].

It has been reported in many literatures that the impact of ENSO is not spatially coherent over Indonesia, depending on intensity, duration, timing, and local setting of geography [5]. The precise information on the upcoming ENSO will enable the government to design a suitable policy related to impact mitigation strategy. In this context, knowledge of the skill of ENSO forecast is an essential requirement.

2. Data and Method

Several methods can be used to conduct a simple assessment on the skill of JMA Ensemble Prediction System (EPS) and NOAA Climate Forecast System version 2 (CFSv2) ENSO prediction. Meteorological Organization (WMO) Standard Verification System for Long Range Forecast (SVS-LRF) parameter will be applied for this study. Some of them are Pearson Correlation, Mean Square Skill Score (MSSS), and Root Mean Squared Error (RMSE). Square Skill Score (MSSS) and Pearson Correlation method will be applied for this research as part of SVS-LRF [6]. Both ENSO prediction verification results also compared each other using Student’s t-test.

The ENSO forecast data released by JMA is obtained from the ENSO JMA forecast archive file (data can be accessed via https://ds.data.jma.go.jp/tcc/tcc/gpv/model/CPS2/3-mon/MGPV/YYYYMM/surflPss_mb/YYYYMM) [7], where YYYY is input for years and MM is input for months. The data is available from June 2015 to December 2019. This forecast data consists of three lead times. Lead time 1; forecasts for the next month, lead time 2; forecasts for the next two months, and lead time 3; forecasts for the next three months. For more details, please see the following Table 1 illustration.

Table 1. Illustration of Lead Time JMA ENSO forecast

| Issued Period | Feb     | Mar     | ……   | Dec            |
|--------------|---------|---------|-------|----------------|
| Jan          | Lead Time 1 | Lead Time 2 | ……   | Lead Time 11   |
| Feb          | :       | Lead Time 1 | Lead Time 2 | Lead Time 10   |
| :            |         | :       | Lead Time 1 | Lead Time …    |
| Jan          |         |         |       | Lead Time …    |

The ENSO forecast data released by NCEP is obtained from the ENSO NCEP forecast archive file (data can be accessed via https://iri.columbia.edu/~forecast/ensofcst/Data/ensofcst_ALLto0520) [8]. It is available from JJA 2015 to OND 2019. The product is issued at three-monthly scale and consists of three lead times. For more details, please see the following Table 2 illustration.

Table 2. Illustration of Lead Time for NCEP ENSO forecast

| Issued Period | JFM     | FMA     | ……   | DJF             |
|--------------|---------|---------|-------|----------------|
| Jan          | Lead Time 1 | Lead Time 2 | ……   | Lead Time 11   |
| Feb          | :       | Lead Time 1 | Lead Time 2 | Lead Time 10   |
| :            |         | :       | Lead Time 1 | Lead Time …    |
| Jan          |         |         |       | Lead Time …    |

The ENSO data observation was obtained from COBE SSTA data and accessed via TCC-JMA iTacs tools. iTacs tools is an application which was developed by JMA to help National Meteorological and Hydrological Services (NMHSs) provide climate status monitoring information and prediction.
2.1. Pearson Correlation
The correlation coefficient \( r \) is a measure to determine the relationship (instead of difference) between two quantitative variables (interval/ratio) [9]. In this study, Pearson correlation is used to measure the relationship between ENSO forecast data and ENSO observation data. Pearson correlation coefficient \( r \) for two sets of values, \( x \) and \( y \), is given by the formula [10]:

\[
 r = \frac{\sum(x-x)(y-y)}{\sqrt{\sum(x-x)^2 \sum(y-y)^2}}
\]  
(1)

Correlation coefficient \( r \) close to positive 1 indicates a strong positive correlation. Its means forecast values similar to observed values. On the other hand, the correlation coefficient is close negative 1 indicates a strong negative correlation. Its means forecast values not similar with observed value.

2.2. Mean Square Skill Score (MSSS)
Mean Square Skill Score (MSSS) value will provide a comparison of forecast performance relative to forecasts of climatology [6]. The three terms of the MSSS decomposition provide valuable information on phase errors (through forecast/observation correlation), amplitude errors (through the ratio of the forecast to observed variances) and overall bias. MSSS can be calculated using equations [6]:

\[
 MSSS_j = 1 - \frac{MSE_j}{MSE_{cj}}
\]

(2)

where:
- \( MSE_j \): Means Square Error of the forecasts
- \( MSE_{cj} \): Means Square Error of the climatology forecast

Positive MSSS values indicate forecast model performances are better than climatology forecast. On the other hand, negative MSSS values can be interpreted as the climatology model have better performance compared to the forecast model.

2.3. Student T-test Score
Student T-test is used to compare the means of two groups. In this Study, the t-test is used to compared the means of JMA and NCEP verification results. The aim of conducting this t-test is to examine whether there is a significant difference between the verification results from NCEP and JMA, so the best information on the prediction of ENSO can be used as a reference in ENSO monitoring. In the student t-test. The data used were correlation data for each month from the ENSO verification results issued by JMA and NCEP (Pearson correlation between NCEP Nino 3.4 with Nino 3.4 observation and Pearson correlation between JMA Nino 3.4 with Nino 3.4 observation). Student t-test Score can be calculated using equations [11]:

\[
 t = \frac{X_1-X_2}{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^{1/2}}
\]

(3)

where:
- \( X \): mean of samples
- \( n \): number of samples
- \( s \): variance of samples

The hypothesis for this test is:

\( H_0 \): There is no the difference in the verification results of JMA and NCEP forecast
There is the difference in the verification results of JMA and NCEP forecast

Test criteria: Reject $H_0$ if $p_{value} < \alpha$, accept in other ways.

3. Performance of ENSO Predictions

3.1. Performance of ENSO Predictions Issued By JMA

By using the Pearson and MSSS Correlation method, the results of ENSO verification for the June 2015 - December 2019 period issued by JMA are as follows:

Figure 1. Performance of ENSO predictions Issued by JMA

Figure 1 shows the results of verification for ENSO index issued by JMA. The correlation test shows high correlation of ENSO forecast for 1 to 3 months ahead. This means ENSO forecast issued by JMA has a high phase similarity with its observational value. Verification using MSSS method also shows similar results with correlation method, where positive MSSS is dominant result. It means ENSO Prediction model issued by NCEP CFS2 is better than climatology (in terms of bias magnitude) for 1 to 3 months ahead.

Using the Pearson Correlation and MSSS methods, the results of ENSO verification for the June 2015 - December 2019 period issued by JMA for each month are as follows:

Figure 2. Performance of Nino 3.4 Prediction Issued by JMA using Correlation Method
The results of skill assessment at monthly scale as shown in Figure 2 and Figure 3. In general, the JMA ENSO forecast has good skills except those issued in May-August. For May-August period, the correlation decrease, particularly for lead time of 2 and 3 months and the MSSS scores are negative (mostly for lead time of 1.5 and 2.5 months) indicating that the forecast has no added value compared to its climatology.

3.2. Performance of ENSO Predictions Issued By NCEP

By using the Pearson and MSSS Correlation method, the results of ENSO verification for the June 2015 - December 2019 period issued by NCEP are as follows:

Figure 4 shows the results of verification for ENSO index issued by NCEP. The correlation test shows that the ENSO forecast is highly correlated with observation with coefficient of correlation around 0.8-1. Based on MSSS method, it is found that positive score is dominant result. The detailed result for correlation test at three-monthly scale is shown in figure 5 while that for assessment using MSSS method is presented in figure 6. Generally, the NCEP ENSO forecast has good skill except those issued in May-June-July (MJJ) – August- September-October (ASO). For MJJ - ASO period, the correlation decrease particularly for lead time of 3 periods and the MSSS scores are negative (mostly for lead time of 2 and 3 periods). This result indicates that that the forecast has no added value compared to its climatology. The same result is also shown by the prediction of ENSO by JMA, in the mid-year period, the skill of ENSO forecast tends to be lower.
Figure 5. Performance of Nino 3.4 Prediction Issued by NCEP using Correlation Method

Figure 6. Performance of Nino 3.4 Prediction Issued by NCEP using MSSS Method

3.3. Performance of ENSO Predictions Issued by JMA and NCEP
Verification results were compared using the student’s t-test. The results for this test are as follows:

| Lead Time | \( t \)  | \( df \)  | \( p_{value} \) |
|-----------|-------|--------|----------------|
| Lead Time 1 | -0.50234 | 16.859  | 0.6219         |
| Lead Time 2 | 0.09843  | 21.979  | 0.9225         |
| Lead Time 3 | -0.1329  | 21.153  | 0.8955         |

Where \( t \) is student t-test value, \( df \) is degrees of freedom. Based on table 3, it can be concluded that the \( p_{value} > \alpha = 0.05 \), so \( H_0 \) is accepted. Using the 95% confidence level, it can be concluded that there is no difference in the verification results of JMA and NCEP forecast. Both models show lower score for forecasting ENSO in the mid-year period.

4. Conclusion
ENSO Prediction issued by JMA and NCEP has a good skill on forecasting 1 to 3 months lead time, indicated by high correlation coefficient and positive value of MSSS score. However, the skill of both JMA and NCEP products reduce for May-August period, suggesting that careful interpretation is needed for ENSO forecast issued on the mentioned period. By using student's t-test, there is no difference in the verification results of JMA and NCEP forecast.
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