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Performance Improvement for Hotspot Prediction Model Using SBi-LSTM-XGBoost and SBi-GRU-XGBoost

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Abstract

Iaculis nunc sed augue lacus viverra vitae congue eu consequat ac felis donec et odio pellentesque diam volutpat commodo sed egestas egestas fringilla phasellus faucibus scelerisque eleifend donec pretium vulputate sapien nec sagittis aliquam malesuada bibendum arcu vitae elementum curabitur vitae nunc sed velit dignissim sodales ut eu sem integer vitae justo eget magna fermentum iaculis eu non diam phasellus vestibulum lorem sed risus ultricies tristique nulla aliquet enim tortor at auctor urna nunc id cursus metus aliquam eleifend mi in nulla posuere sollicitudin aliquam ultrices sagittis orci a scelerisque purus semper eget duis at tellus at urna condimentum mattis pellentesque id nibh tortor id aliquet lectus proin nibh nisl condimentum id venenatis a condimentum vitae sapien pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas sed tempus urna et pharetra pharetra massa massa ultricies mi quis hendrerit dolor magna eget est lorem ipsum dolor sit amet consectetur adipiscing elit pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas integer eget aliquet nibh praesent tristique magna sit amet purus gravida quis blandit turpis cursus in hac habitasse platea dictumst quisque sagittis purus sit amet volutpat consequat mauris nunc congue nisi vitae suscipit tellus mauris a diam maecenas sed enim ut sem viverra aliquet eget sit amet tellus cras adipiscing enim eu turpis egestas pretium aenean pharetra magna ac placerat vestibulum lectus mauris.

Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

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2. Related Works

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3. Method

3.1. Data Collections

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3.2. Data Preprocessing

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$$Normalization = a + \frac{\left(x - min\,(x)\right) * (b - a)}{max(x) - min(x)} \tag{1}$$

3.3. Exploration Data Analysis

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3.4. Time Series Analysis

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$$\Delta Y_t = \alpha_0 + \alpha_1 t + \gamma Y_{t-1} + \beta_i \sum_{i=1}^{p} \Delta Y_{t-i} + e_t \tag{2}$$

$$\bar{t_a} = t_a \left(\frac{Y_0}{f_0}\right)^{1/2} - \frac{T(f_0 - Y_0)\left(se(\hat{\alpha})\right)}{2 * f_0^{1/2} * s} \tag{3}$$

$$Y_t = \delta_t + r_t + e_t \tag{4}$$

3.5. Data Splitting

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3.6. Model Prediction Hotspot

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$$f_t = \sigma\left(w_f . [s_{t-1}, x_t] + b_f\right) \tag{5}$$

$$i_t = \sigma(w_i . [s_{t-1}, x_t] + b_i) \tag{6}$$

$$\widetilde{C_t} = \tanh(w_c . [s_{t-1}, x_t] + b_c) \tag{7}$$

$$C_t = f_i * C_{t-1} + i_t * \widetilde{C_t} \tag{8}$$

$$o_t = \sigma(w_0 . [s_{t-1}, x_t] + b_0) \tag{9}$$

$$s_t = \sigma * \tanh{(C_t)} \tag{10}$$

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$$r_t = \sigma(W_r x_t + U_r h_{t-1} + b_r) \tag{11}$$

$$z_t = \sigma(W_z x_t + U_z h_{t-1} + b_z) \tag{12}$$

$$\hat{h}_t = \phi(W_h x_t + U_h (r_t \odot h_{t-1}) + b_h) \tag{13}$$

$$h_t = \phi(1 - z_t) \odot h_{t-1} + z_t \odot \hat{h}_t \tag{14}$$

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Algorithms	:	SBi-LSTM-XGBoost
Input	:	xtrue, ytrue, lstm_pred
Output	:	xgb_pred

```
# 1. calculate residuals
residuals = ytrue - lstm_pred[:, 0]

# 2. xgboost model on residuals
xgb_model = XGBRegressor()

# 3. fitting models
xgb_model.fit(xtrue, residuals)

# 4. predict models
predictions = xgb_model.predict(xtrue)

# 5. Combine Model with XGBoost predictions
xgb_predictions = lstm_pred[:, 0] + predictions
```

Algorithms	:	SBi-GRU-XGBoost
Input	:	xtrue, ytrue, gru_pred
Output	:	xgb_pred

```
# 1. calculate residuals
residuals = ytrue - grud_pred[:, 0]

# 2. xgboost model on residuals
xgb_model = XGBRegressor()

# 3. fitting models
xgb_model.fit(xtrue, residuals)

# 4. predict models
predictions = xgb_model.predict(xtrue)

# 5. Combine Model with XGBoost predictions
xgb_predictions = grud_pred[:, 0] + predictions
```

3.7. Model Evaluations

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$$R = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \tag{15}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |\hat{y}_i - y_i| \tag{16}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2} \tag{17}$$

$$MAPE = \sum_{i=1}^{n}\left|\frac{\hat{y}_i - y_i}{y_i}\right| \tag{18}$$

4. Results and Discussion

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4.1. Data Collections

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Tabel 1. Metdadata of dataset

Characteristics	SST Nino 3.4	Index ONI	Index SOI	Hotspot
Count	276,00	276,00	276,00	276,00
Mean	0,01	-0,03	0,39	595,02
Std	0,77	0,82	1,53	1664,50
Min	-1,59	-1,64	-5,20	3,00
25%	-0,55	-0,61	-0,60	20,00
50%	-0,07	-0,14	0,30	54,00
75%	0,47	0,47	1,32	255,75
Max	2,72	2,64	4,80	14437,00

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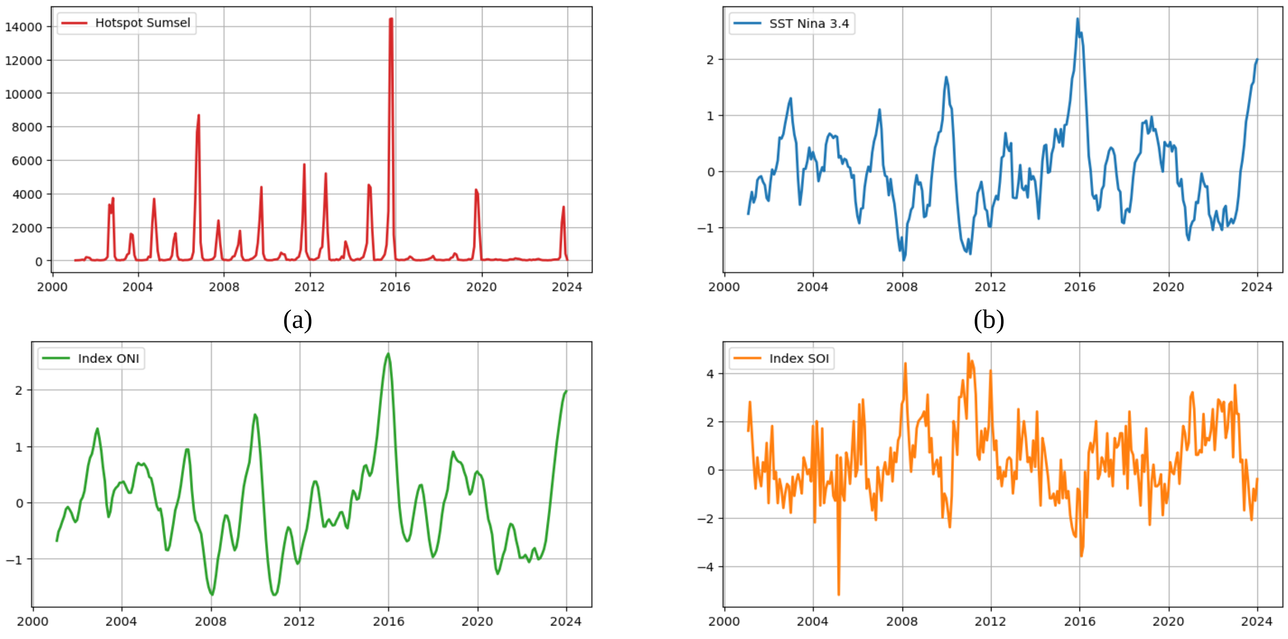

(a) (b) (c) (d)

Fig 2. Results of Data Collections

4.2. Data Preprocessing

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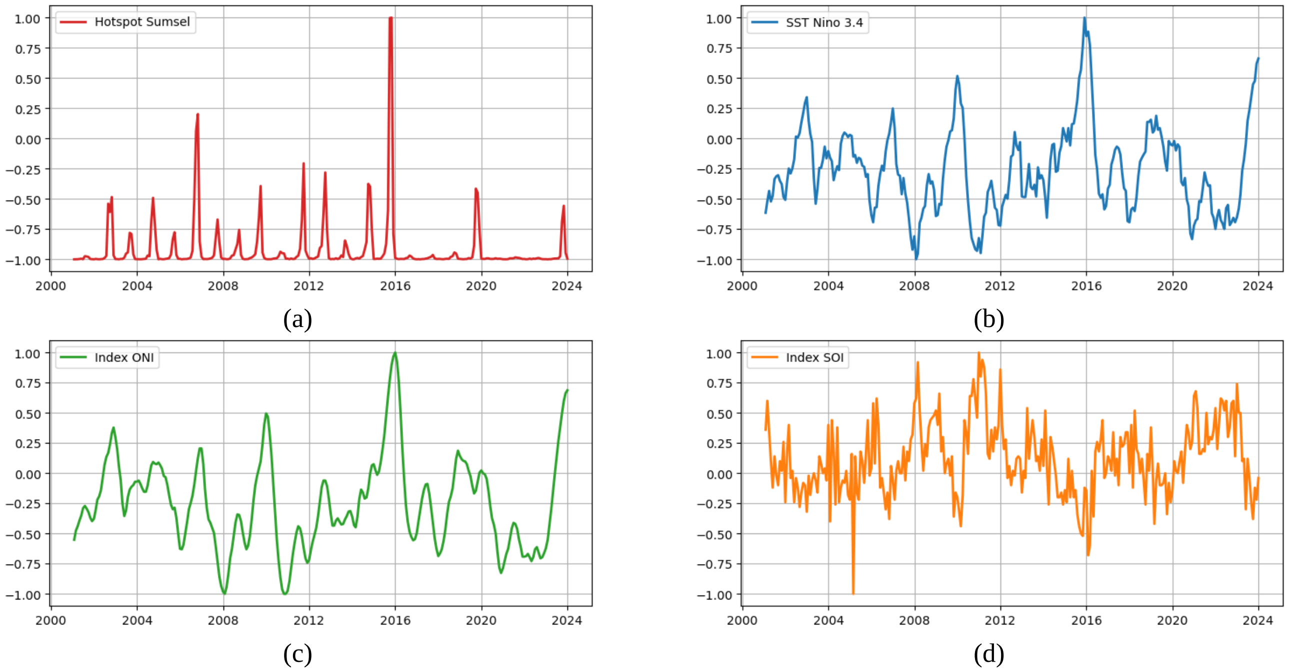

Fig 2. Results of normalized min-max

4.3. Exploration Data Analysis

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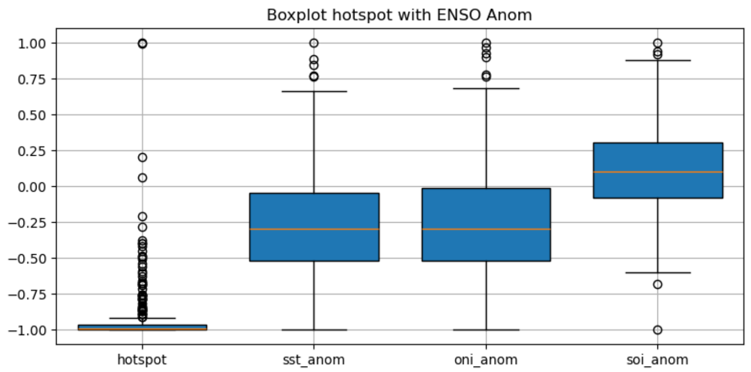

Fig 3. Hasil deteksi pencilan

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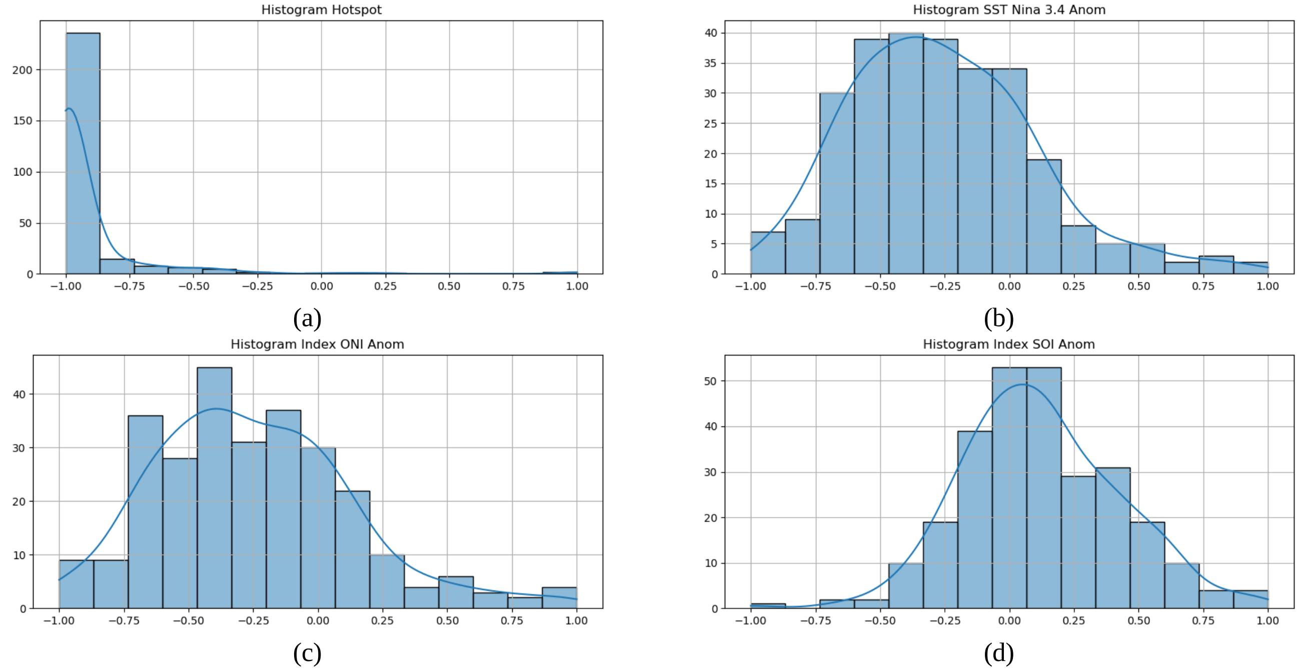

Fig4. Analisa distribusi data

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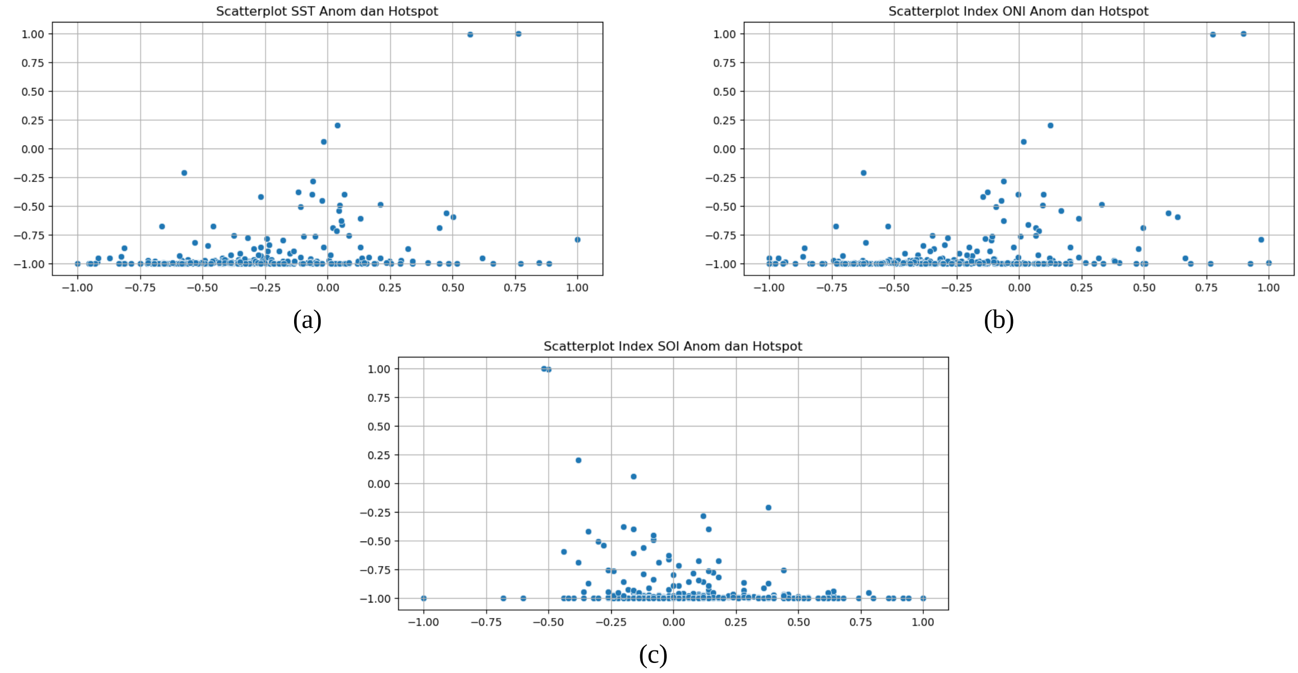

Fig5. Analisa linieritas

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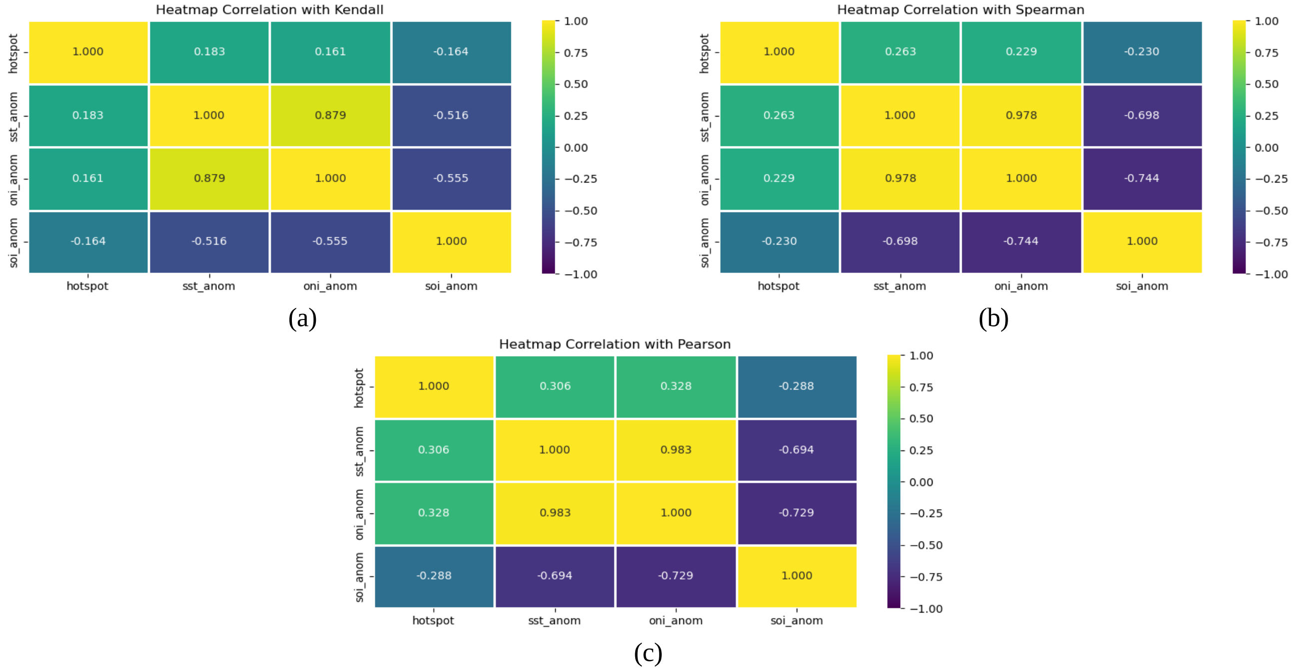

Fig6. Analisa korelasi antar fitur

4.4. Time Series Analysis

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Tabel 2. Statistical Analysis of Stationarity

Methods	**P-value**	**Critical values**		
		1%	**5%**	**10%**
ADF				
Lag 1	0,000	-3,99	-3,43	-3,14
Lag 6	0,000	-3,99	-3,43	-3,14
Lag 12	0,004	-3,99	-3,43	-3,14
Lag 24	0,074	-4,00	-3,43	-3,14
PP				
Lag 1	0,000	-3,99	-3,43	-3,14
Lag 6	0,000	-3,99	-3,43	-3,14
Lag 12	0,000	-3,99	-3,43	-3,14
Lag 24	0,000	-3,99	-3,43	-3,14
KPSS				
Lag 1	0,815	0,22	0,15	0,12
Lag 6	0,304	0,22	0,15	0,12
Lag 12	0,232	0,22	0,15	0,12
Lag 24	0,201	0,22	0,15	0,12

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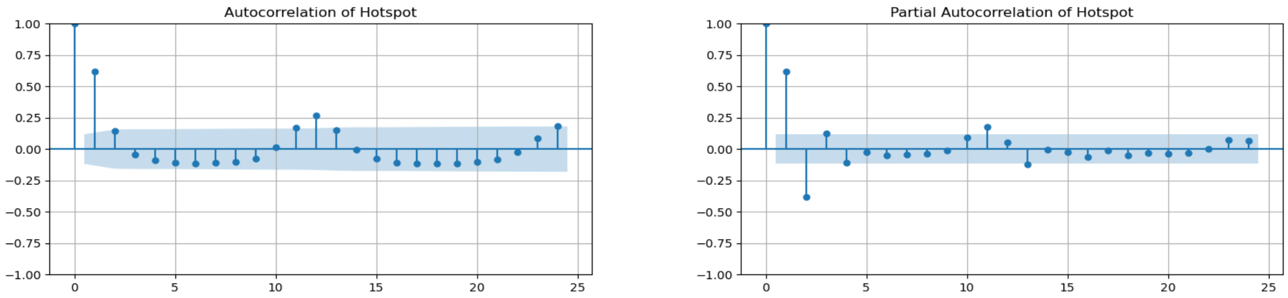

(a) (b)

Fig 7. Analisa ACF dan PACF

4.5. Data Splitting

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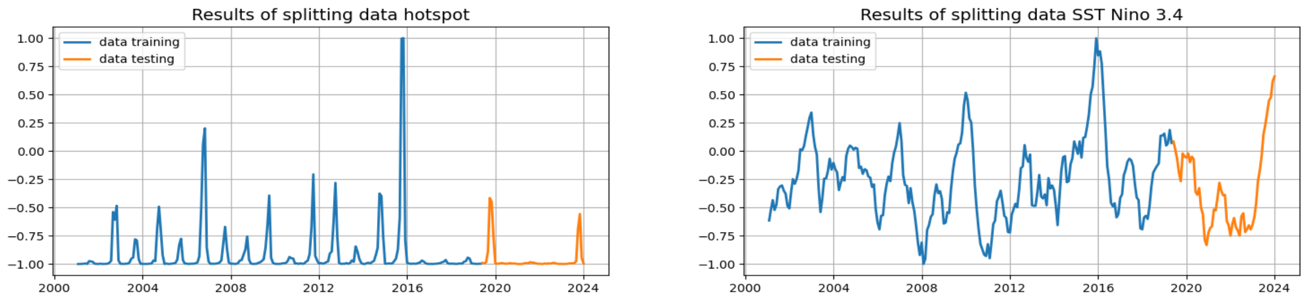
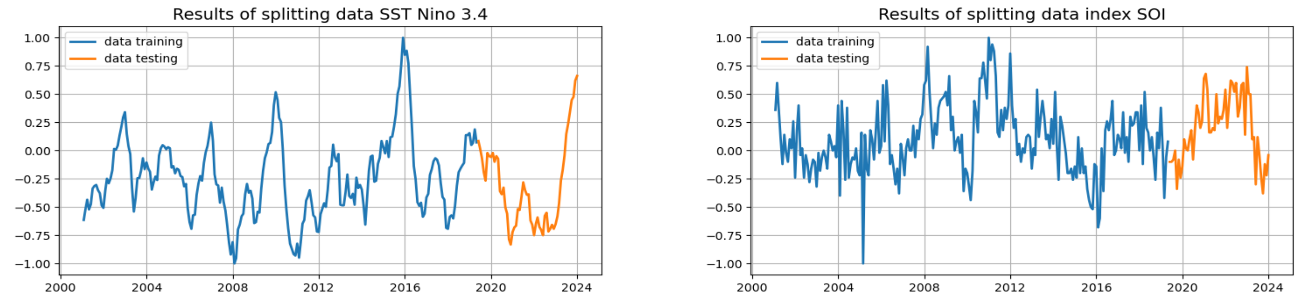


(a) (b)



(c) (d)

Fig8. Analisa distribusi data

4.6. Model Prediction Hotspot

4.6.1 Initialisation of neural network parameters and model

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Tabel 3. Initialization of tuning hyperparameters

Parameter tuning	**Values**
Activation function	ReLU, SeLU, ELU, Softplus.
Optimizers	Adam, Adamax, RMSprop, SGD.
Dropout	0.05, 0.10, 0.15, 0.20, 0.25
Batch Size	2, 4, 8, 16, 32
Epoch	1500

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Desain NN yang dibuat:

- 1 input layers dengan 4 neuron (hotspot, sst nina 3.4, index oni, index soi pada t-1 sebagai input)
- 3 hidden layers dengan 10 neuron. Setiap hidden layers mewakili 1 layes lstm atau gru. (Sehingga terdapat 3 layers lstm atau gru yang ditumpuk).
- 1 dropout layer
- 1 output layers (hotspot pada t+1 sebagai output)

Note :
Desain ini berlaku umum untuk M1 dan M2.

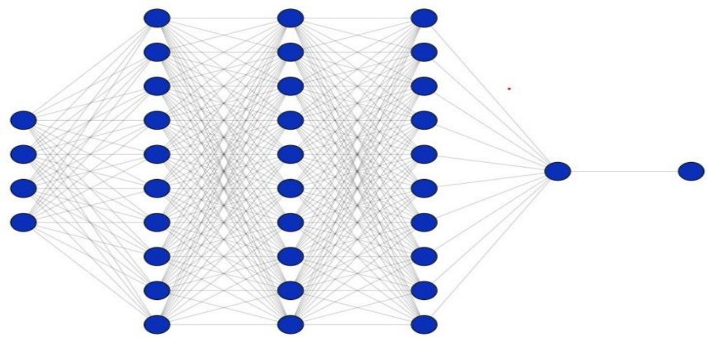

Fig 9. Desain Neural Network for LSTM-RNN dan GRU-RNN

4.6.2 Results of finding the best parameters.

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Tabel 4. Results of hyperparameter tuning with gridsearch algorithm

Algorithms	**Parameter Tuning**				
	Activation function	**Optimizers**	**Dropout**	**Batch Size**	**Epoch**
SBi-LSTM					
Univariate	SeLU	SGD	0,15	8	1500
Multivariate	ReLU	RMSprop	0.20	32	
SBi-GRU					
Univariate	SeLU	SGD	0,25	8	1500
Multivariate	ReLU	RMSprop	0.20	16	1500

Univariate = hanya titik panas (M1)
Multivariate = titik panas + enso (M2)

4.6.3 Results of training and validation models

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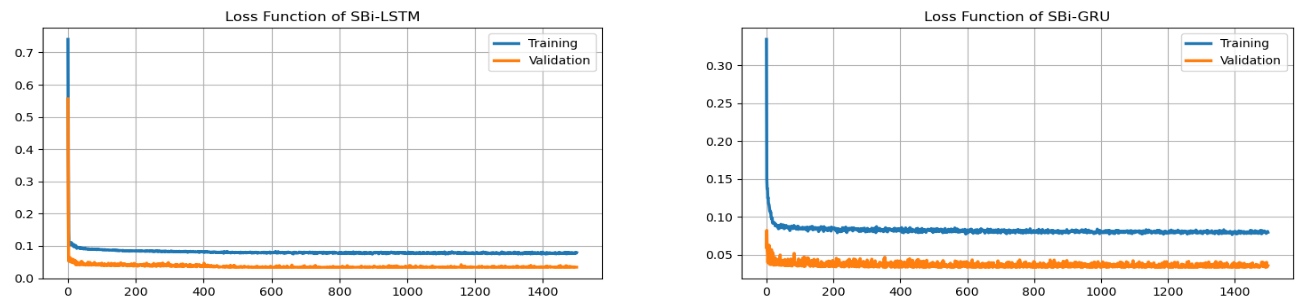

(a) (b)

Fig 10. Results of training models univariate

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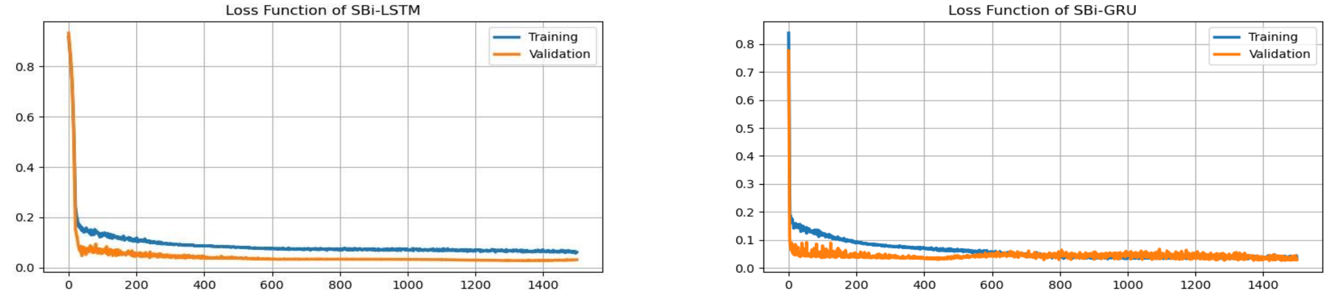

(a) (b)

Fig11. Results of training models multivariate

4.6.3 Results of prediction hotspot with univariate and multivariate models

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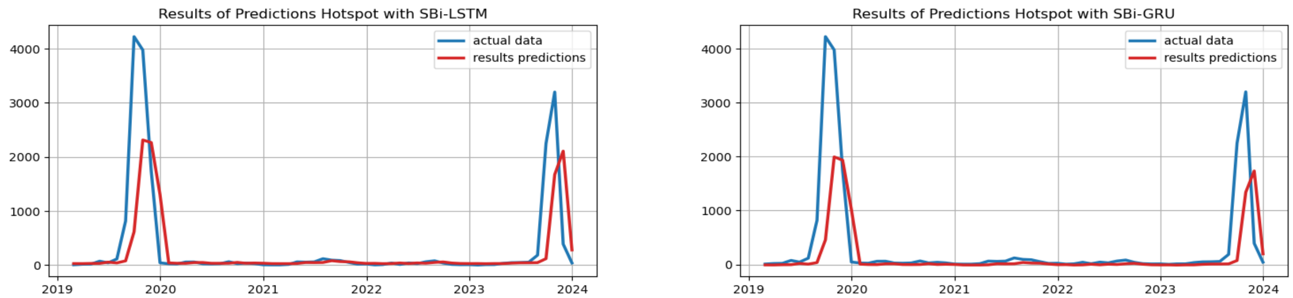

(a) (b)

Fig12. Results of training models univariate

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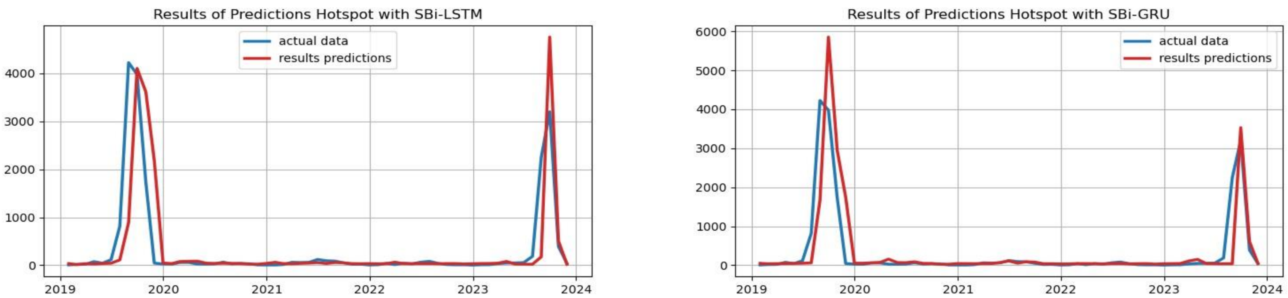

(a) (b)

Fig13. Results of training models multivariate

tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus etnetus et malesuada fames ac turpis egestas. Nam exaugue, semper attempus, tincidunt anibh. Fusce efficitur ex nisl, sed gravida. – Analisa hasil dari proses training dan prediksi tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus etnetus et malesuada fames ac turpis egestas. Nam exaugue, semper attempus, tincidunt anibh. Fusce efficitur ex nisl, sed gravida. – Hasil lengkap prediksi titik panas.

Fig4. Results of prediction hotspot using univariate SBi-LSTM

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des
2019		31	30	33	34	57	43	80	618	2314	2266	1307
2020	44	37	36	50	50	37	36	37	52	37	41	38
2021	30	29	29	32	51	49	51	83	68	64	46	34
2022	35	29	31	42	32	43	38	52	61	41	32	31
2023	31	28	31	31	39	45	46	48	121	1675	2108	282

Fig5. Results of prediction hotspot using multivariate SBi-LSTM

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des
2019		35	14	33	26	36	43	112	890	4102	3613	2180
2020	47	36	78	83	86	45	39	42	40	34	25	22
2021	39	62	35	32	40	46	58	37	59	51	34	31
2022	34	30	33	65	35	34	36	36	33	35	35	27
2023	32	37	38	44	80	24	23	22	175	4755	508	20

Fig6. Results of prediction hotspot using univariate SBi-GRU

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des
2019		55	55	59	60	85	70	106	528	2237	2159	1098
2020	70	62	61	77	77	62	61	63	80	63	68	64
2021	55	54	54	57	78	76	78	109	94	90	73	59
2022	61	54	56	68	57	69	64	79	88	68	57	55
2023	56	53	56	56	66	72	73	75	147	1441	1907	269

Fig7. Results of prediction hotspot using multivariate SBi-GRU

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des
2019		50	36	40	44	48	51	61	1669	5849	2948	1745
2020	53	53	64	72	157	69	66	88	48	44	27	27
2021	43	42	40	43	44	70	111	53	89	81	39	38
2022	34	34	43	42	40	35	44	45	35	40	42	30
2023	39	40	45	112	150	45	42	39	39	3526	608	46

tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus etnetus et malesuada fames ac turpis egestas. Nam exaugue, semper attempus, tincidunt anibh. Fusce efficitur ex nisl, sed gravida. – Analisa hasil dari prediksi selama 5 tahun 2019 – 2023.

Letak kebaharuan dari sisi penerapan SBi-LSTM-XGBoost dan SBi-GRU-XGBoost

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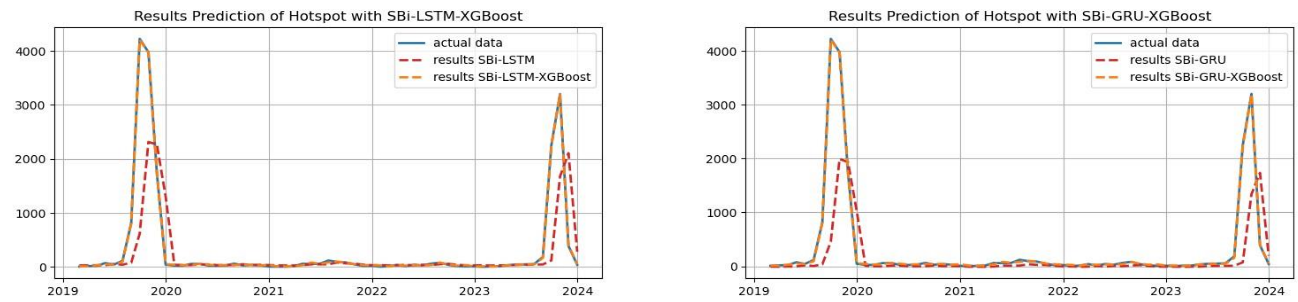

(a) (b)

Fig9. Results of training models univariate

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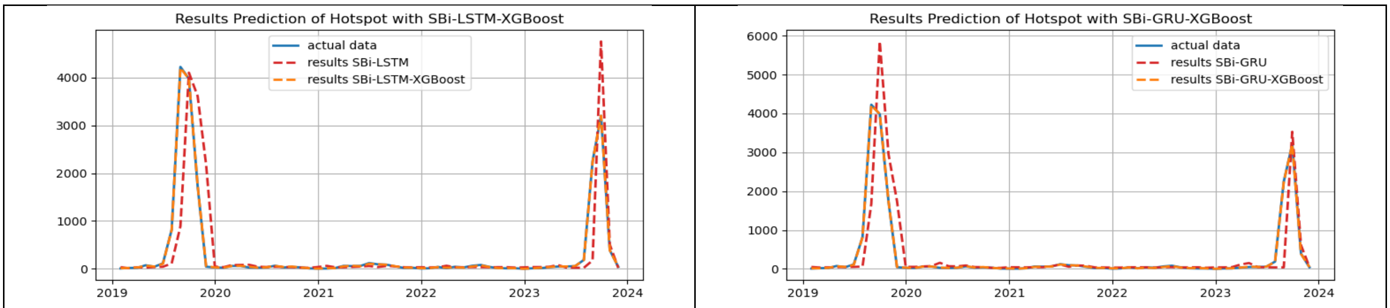

(a) (b)

Fig10. Results of training models multivariate

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Fig8. Results of prediction hotspot using univariate SBi-LSTM-XGBoost

Year	**Month**											
	Jan	**Feb**	**Mar**	**Apr**	**Mei**	**Jun**	**Jul**	**Ags**	**Sep**	**Okt**	**Nov**	**Des**
2019		13	12	32	54	43	96	809	4205	3969	1736	53
2020	43	32	35	61	43	32	35	41	39	41	26	38
2021	12	12	12	35	85	60	85	101	87	50	36	33
2022	29	12	34	27	35	30	38	81	47	26	35	13
2023	13	11	13	34	40	47	48	168	2238	3190	402	49

Fig9. Results of prediction hotspot using multivariate SBi-LSTM-XGBoost

Year	**Month**											
	Jan	**Feb**	**Mar**	**Apr**	**Mei**	**Jun**	**Jul**	**Ags**	**Sep**	**Okt**	**Nov**	**Des**
2019		11	18	28	65	49	104	812	4202	3973	1743	57
2020	30	26	58	62	45	24	32	62	39	48	27	12
2021	4	13	14	53	64	55	106	96	86	55	27	23
2022	13	14	37	23	33	24	50	73	38	14	16	12
2023	1	12	21	37	51	50	57	184	2236	3202	388	46

Fig10. Results of prediction hotspot using univariate SBi-GRU-XGBoost

Year	Month											
	Jan	**Feb**	**Mar**	**Apr**	**Mei**	**Jun**	**Jul**	**Ags**	**Sep**	**Okt**	**Nov**	**Des**
2019		13	12	32	42	43	94	808	4207	3968	1735	52
2020	46	33	36	60	44	33	36	44	38	44	29	39
2021	12	11	11	35	85	63	85	101	87	51	32	33
2022	29	11	34	29	35	30	39	82	46	29	35	13
2023	13	10	13	34	41	47	48	167	2238	3189	402	49

Table11. Results of prediction hotspot using multivariate SBi-GRU-XGBoost

Year	Month											
	Jan	**Feb**	**Mar**	**Apr**	**Mei**	**Jun**	**Jul**	**Ags**	**Sep**	**Okt**	**Nov**	**Des**
2019		14	14	25	70	51	105	814	4207	3985	1737	49
2020	31	24	57	61	33	25	32	70	34	48	26	13
2021	11	6	17	52	59	60	113	96	86	59	26	24
2022	14	14	36	14	31	24	49	73	35	20	21	13
2023	4	12	14	34	56	51	57	179	2239	3199	386	48

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4.7. Model Evaluations

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Table 12. Results of model evaluation using univariate models

Runing	SBi-LSTM				SBi-GRU			
	Model evaluations				Model evaluations			
	R	**MAE**	**RMSE**	**MAPE**	**R**	**MAE**	**RMSE**	**MAPE**
1	0,6430	0,0343	0,0956	0,0566	0,6473	0,0338	0,0973	0,0581
2	0,6389	0,0344	0,0961	0,0569	0,6457	0,0337	0,0974	0,0577
3	0,6417	0,0344	0,0960	0,0569	0,6460	0,0352	0,0971	0,0594
4	0,6409	0,0342	0,0958	0,0569	0,6463	0,0343	0,0979	0,0586
5	0,6436	0,0358	0,0951	0,0581	0,6479	0,0335	0,0972	0,0576
6	0,6420	0,0341	0,0958	0,0566	0,6462	0,0337	0,0983	0,0583
7	0,6390	0,0347	0,0959	0,0572	0,6484	0,0356	0,0969	0,0597
8	0,6359	0,0345	0,0963	0,0571	0,6482	0,0341	0,0973	0,0581
9	0,6417	0,0351	0,0955	0,0575	0,6452	0,0334	0,0977	0,0577
10	0,6400	0,0352	0,0958	0,0578	0,6484	0,0337	0,0965	0,0574
11	0,6456	0,0339	0,0960	0,0570	0,6475	0,0353	0,0964	0,0591
12	0,6427	0,0342	0,0957	0,0567	0,6439	0,0336	0,0974	0,0577
13	0,6419	0,0342	0,0963	0,0571	0,6456	0,0335	0,0975	0,0577
14	0,6442	0,0344	0,0954	0,0567	0,6458	0,0341	0,0973	0,0583
15	0,6458	0,0344	0,0952	0,0568	0,6462	0,0335	0,0973	0,0575

Table 13. Summary Results of model evaluation using univariate models

Experiment	SBi-LSTM				SBi-GRU			
	Model evaluations				Model evaluations			
	R	**MAE**	**RMSE**	**MAPE**	**R**	**MAE**	**RMSE**	**MAPE**
Minimum	0,6359	0,0339	0,0951	0,0566	0,6439	0,0334	0,0964	0,0574
Maximum	0,6458	0,0358	0,0963	0,0581	0,6484	0,0356	0,0983	0,0597
Avegare	0,6418	0,0345	0,0958	0,0571	0,6466	0,0341	0,0973	0,0582

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Table 14. Results of model evaluation using multivariate models

Runing	**SBi-LSTM Model evaluations**				**SBi-GRU Model evaluations**			
	R	**MAE**	**RMSE**	**MAPE**	**R**	**MAE**	**RMSE**	**MAPE**
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

Table 15. Summary Results of model evaluation using univariate models

Experiment	**SBi-LSTM Model evaluations**				**SBi-GRU Model evaluations**			
	R	**MAE**	**RMSE**	**MAPE**	**R**	**MAE**	**RMSE**	**MAPE**
Minimum								
Maximum								
Avegare								

5. Conclusion

Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

Acknowledgment *(HEADING 5)*

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g.” Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

References

The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first ...”

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors’ names; do not use “et al.”. Papers that have not been published, even if they have been submitted for publication, should be cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

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