REVISION LIST (Referee #3)

Title:	Extending the Coverage Area of Regional Ionosphere Maps Using a Support Vector Machine Algorithm
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Date:	November 19, 2018

Dear Referee #3

Thanks for your comments on this manuscript. The authors have incorporated all the comments in revised manuscript, which have been helpful to improve the manuscript. The revised or new sentences are colored in red in the revised manuscript.

< REVIEWER 3 >

1) In page 7 line 2 you say that correlation coefficient between the two adjacent data for F10.7 cm, Kp and SSN is 0.93, 0.863, 0.852. I think that correlation analysis should be between F10.7 cm-TEC, Kp-TEC, SSN-TEC. According to these results, you will do weighting and this weighthing affects your results. The other thing is that F10.7 cm is only one value for one day, therefore its affect can not be monitored effectively in a day. You can obtain Kp value from https://omniweb.gsfc.nasa.gov/form/dx1.html with one hour resolution. You should also take into account DsT index which give information about geomagnetic activity of ionosphere. You can also more precise results by adding this DsT index.
(a) The correlation analysis of TEC with DsT, F10.7, Kp, or SSN, has been recently performed, and details results are presented in the supplement of this revision list. Due to the complicated nature of the ionosphere correlation, the correlation is not clearly shown in the plots. However, Dst shows a more correlation than the other parameters as the reviewer suggested. Since the NN or the SVM uses a complicated weighting structure (rather than a linear weighted combination), individual weights cannot be assigned in the algorithm. Sentences on this correlation analysis have been added. <Sec.2, p.2> <Sec.4, pp.9-10> (b) The 1-hour Kp index that the reviewer suggested had been investigated. At this moment, they provides only 3-hr data online; 1-hour Kp data seems to be the same as 3-hr data, i.e. simple extension. Our estimation algorithm's dependency on the environmental parameters, e.g. Kp or F10.7, is much less than the inner ionosphere data. The effect of Kp update rate may be more

important during geomagnetic storm, and it can be investigated as a further research topic. Discussion on this environmental parameter update rate had been added in the second revision of the manuscript.
<Sec.4, p.8, lines 1-12>

(c) Based on this correlation analysis, we have rerun all the estimation process after replacing Kp with Dst. The detailed estimation results are presented in the supplement. Our preliminary results show that Dst is not better than Kp for the estimation. These results may be due to incomplete optimization for Dst use or Dst nature. Optimization with Dst can be good as a further research topic. The Dst results (Figures and table) have not been added to the revised manuscript, but a discussion on these experiments has been added.
<Sec.4, pp.9-10>

2) In this paper, I cannot see any discussion, therefore your results can not be confirmed. Please investigate other studies and compare your result.

We have added more discussion for analyzing the results after reviewing additional papers on machine learning ionosphere researches. However, no one have performed similar concept of research (the ionospheric delay extrapolation using inner data points) as far as the authors' know, direct comparison or discussion with preceding researches was not possible. In depth analysis clarified the correlation between the ionosphere spatial gradient and the estimation accuracy. Sentences on the new discussion and several references have been added.

<Sec.5.1, pp.11-13> <Sec.5.2, p.14> <Ref., pp.15-16>

3) Conclusion also should be explained detaily. You mention about differences but you did not any comment on this. Please explain these differences.

We have added some paragraphs on the ionospheric delay gradient which explains the high estimation error at the north point unlike other ionosphere estimation researches. For explaining the accuracy difference between the SVM and the NN, the inherent advantage of the SVM over the NN.

<Sec.6, p.15>

< Supplement for comment #1>

(a) Correlation analysis

Correlation plots between TEC and environmental parameter are generated using one year of data (from Oct. 1, 2013 to Sep. 30, 2014). The TEC value at S5 point is used for the analysis, and four parameters, Dst, Kp, F10.7, and SSN, are considered.

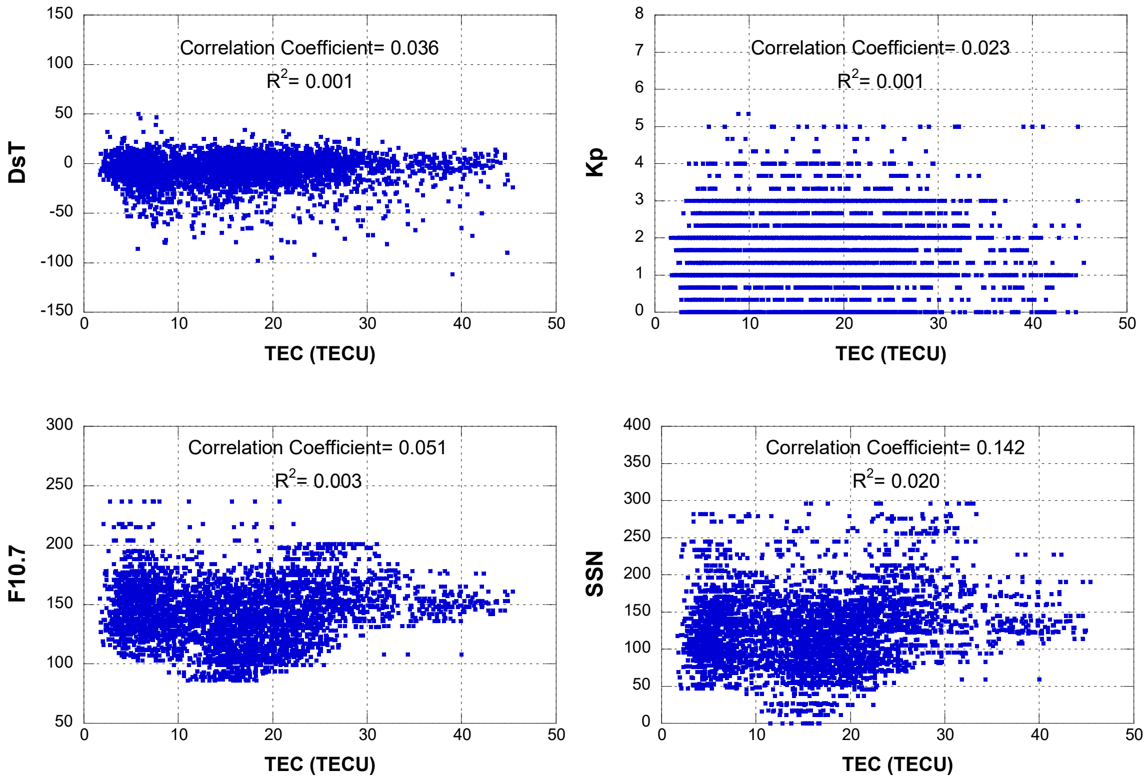

Figure 1. The correlation between ionospheric delay and Dst, Kp, F10.7, and SSN

The correlation coefficients of Dst, Kp, F10.7, and SSN are 0.036, 0.023, 0.051, and 0.142, respectively. The correlation coefficient is lower than expected, but Dst shows a slightly larger value than Kp as the reviewer suggested. Based on this correlation analysis, another set of experiments had been performed with Dst. Since the TEC estimate is obtained from complicated non-linear weighted sum of the environmental parameters, a linear correlation does not directly affects the estimation accuracy.

(c) Experiments with Dst

Test set of experiments had been performed by using Dst instead of Kp. All the figures and tables were re-generated using Dst, but few figures are selected for the comparison. Some plots have different y-axis limits.

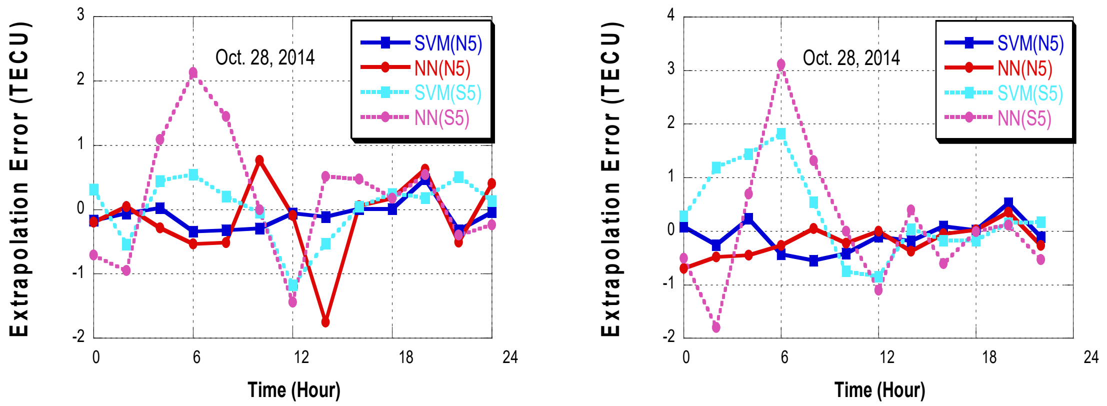

Figure 2. Extrapolation error variations on October 28, 2014 (N5 and S5) using Kp (left) or Dst (right)

In overall, the estimation errors are increased with Dst by both of the SVM and the NN. Especially the error increase at peak ionosphere at 6 UT is significant

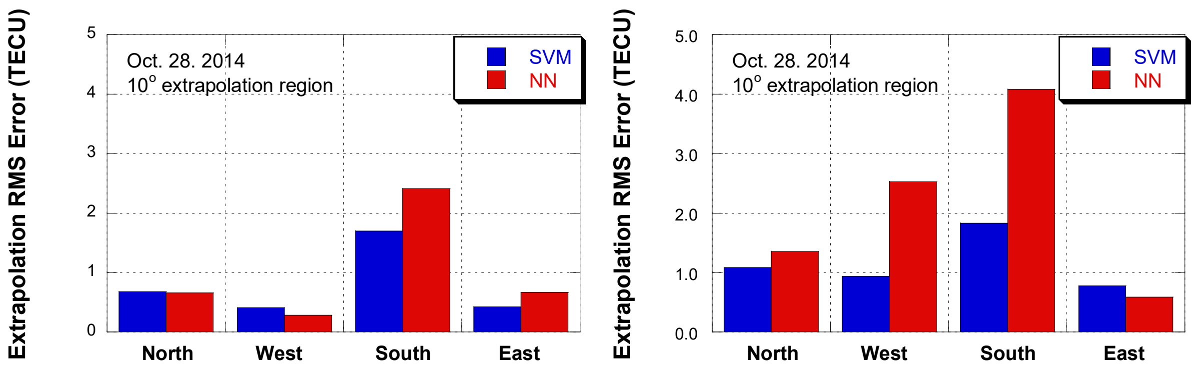

Figure 3. Extrapolation error for each direction (10° point) using Kp (left) or Dst (right)

The estimation error at 10° points are compared in Fig. 3. The overall errors (both of the NN and the SVM) are increased with Dst. The error increase by the NN is more significant than the SVM. It also proves that the NN is less robust than the SVM or more sensitive on input parameters.

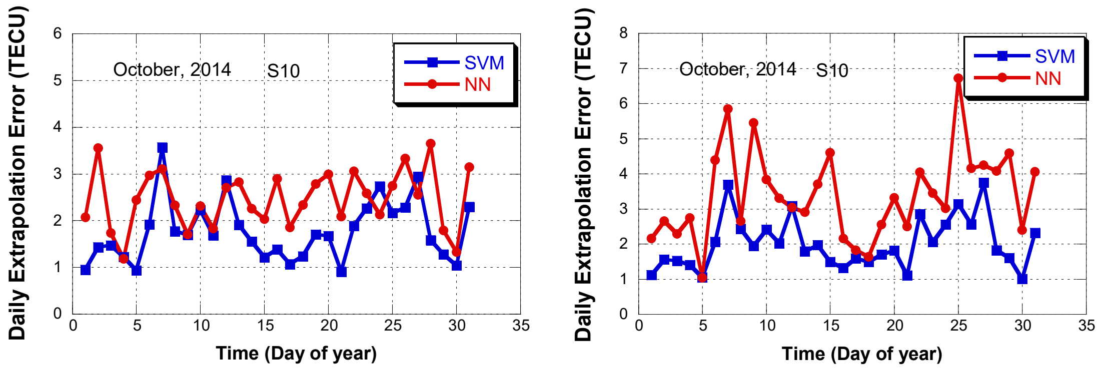

Figure 4. Daily extrapolation RMS error variations in October 2014 (south 10° point) using Kp (left) or Dst (right)

The daily estimation error variations during one-month are compared in Fig.4. The errors of a SVM model is slightly increased, but the errors of a NN models is significantly increased when Dst < -25nT (October 9, 19-21, 28). It means that when the geomagnetic activity is high, the extrapolation performances of a NN model with Dst might be poor unlike the SVM model. Although the geomagnetic activity is low in October 9, the error of a NN model is also increased about 2.70 TECU.

Table 1a. One−month mean of extrapolation errors with Kp (unit= TECU)

Extrapolation region	5°			10°			15°		
	Klob.	SVM	NN	Klob.	SVM	NN	Klob.	SVM	NN
North	14.41	0.32	0.68	13.07	1.02	1.06	12.04	1.97	1.90
East	14.63	0.17	0.20	14.57	0.51	0.71	14.47	1.00	1.13
West	13.38	0.24	0.25	13.29	0.64	0.63	13.12	1.27	1.44
South	25.13	0.57	0.67	24.40	1.89	2.54	26.97	3.58	3.79
Total	16.89	0.33	0.45	16.33	1.01	1.23	16.65	1.95	2.06

Table 1b. **One-month mean of extrapolation errors with Dst (unit= TECU)**

Extrapolation region	5°			10°			15°		
	Klob.	SVM	NN	Klob.	SVM	NN	Klob.	SVM	NN
North	14.41	0.37	0.60	13.07	1.32	1.59	12.04	2.40	2.45
East	14.63	0.37	0.36	14.57	0.83	0.87	14.47	1.28	1.51
West	13.38	0.34	0.36	13.29	0.79	1.15	13.12	1.47	2.97
South	25.13	0.69	1.21	24.40	2.13	**3.62**	26.97	3.78	3.93
Total	16.89	0.44	0.63	16.33	1.27	1.81	16.65	2.31	2.72

The extrapolation RMS errors for all directions and models are compared in Table 1a and 1b. The values changed by using Dst instead of Kp are shown in red. All the errors are increased except of NN error at N5 point. In S10 with NN model, the error is significantly increased because of the poor estimation in period of Dst < -25 nT.