REVISION LIST (Referee #2)

Title:	Extending the Coverage Area of Regional Ionosphere Maps Using a Support Vector Machine Algorithm
Authors:	Mingyu Kim and Jeongrae Kim
Date:	November 12, 2018

Dear Referee #2

Thanks for your comments on this manuscript. The authors have incorporated all the comments in revised manuscript. The revised or new sentences are colored in red in the revised manuscript.

< REVIEWER 2 >

1) The performance of a NN model largely depends on the number of hidden layer neurons used. The authors indicate that they have used 80 hidden layer neurons based on previous studies. The previous study referenced does not give a convincing method to check overtraining of the networks. Also the dataset is entirely different, and the NN architecture is also different. Using a different number of hidden layer neurons may give better results, perhaps better than the SVM method. I therefore suggest that the authors device a system to check performance of the networks (especially on extrapolation datasets), if not, the networks may even over-fit the training data and so perform poorly on extrapolation data. The authors may also choose to indicate/explain in the manuscript that the observation they report is not generalized (but limited to the case of their NN training) because a carefully done NN may give better results, even than the SVM does.
The parameter optimization of the SVM and NN models had been already performed but not included in the manuscript. We added a description for the optimization results. SVM has some advantages over NN as described in Section 1. As the reviewer pointed out, the advantage of SVM might be reduced in other ionospheric environments, but ultimate generalized methodology is not within the scope of our research. The authors concluded that the SVM outperforms NN in case of our research after series of computation runs. < Figs. 5 and 6, p.9>

2) There is also information which appears missing in the manuscript. Inputs for the models do not include station locations? How do the models predict different values for different locations? The spatial structure (with station locations) is pre-fixed in the models? How do you query the models for data of, let's say, 10 degrees from the center of your circle? I wonder what applications there are for this method if the spatial structure for the models is pre-fixed.

The proposed algorithm is using fixed locations both for input and output, and it does not require the spatial structure. Other researchers' works on ionosphere prediction used raw GPS TEC measurements at varying IPP (Ionospheric Piercing Point) and the measurement locations should be registered in the input. Our algorithm uses a grid-based ionosphere map with fixed grid points, and their location information is not required as the model inputs.

Our algorithm is to estimate TEC at fixed pre-specified locations. The TEC values at the estimation points are used during training process and their actual location information is not necessary. In order to change the output point, a new training process should be performed. In practice, a gridded ionosphere map is generated from the extrapolation algorithm and the ionospheric delay at specific point, e.g. IPP, can be computed through interpolation. Sentences have been added to emphasize this aspect.

<Sec.2, p.3>

3) Although the authors have used data for South Korea, they do not indicate the implication of this limitation anywhere on the manuscript. Given the spatial variability of the ionosphere, extrapolation schemes for a given region will perform differently for different regional models. For instance, whether the ionospheric ionization should be greater or otherwise in the outer regions is something too arbitrary to decide based on the inner data. And if the outer data will always be required to train the relationship, then the application I see of this work is defeated.

As the reviewer pointed out the ionosphere environment depends on its geomagnetic locations, and our extrapolation algorithm performance might be different at other locations. However, our proposed algorithm is still worth for extending ionosphere map coverage. If the estimation region is changed, a new training and optimization process should be performed. Arbitrary variation of outer points may limit the usability of this algorithm, but it does not imply that this algorithm is useless. In any case, ionosphere variation has some sort of geographical correlation and it is the key concept of this algorithm. Paragraphs on the limitation on the algorithm have been added.

<Sec.5, p.14>

4) Page 2, lines 32-33: It is not clear why two solar activity indicators (F10.7 and SSN) are repeated. Also, how does the method in this work take care of the time lag (up to several hours/days) for geomagnetic storm effects to be observed in the ionosphere?

The extrapolation accuracy with both F10.7 and SSN was better than with F10.7 only in some cases. At S5 region, the 4.4% and 2.9% error reduction was achieved for SVM and NN model, respectively. Based on this experiments, we included SSN in environmental inputs.
For geomagnetic storm, Kp value is included in the input. Although even Kp may have several hours of delay, the ionosphere estimate is much more dependent of its inside ionosphere map input, which responds to geomagnetic storm in real time (since the inner ionosphere map is the output of real-time ionosphere measurements).

<Sec.2, p.2-3>

5) Page 1, lines 37-38: "Kim and Kim (2016) additionally used ionospheric delays in the inner ionospheric coverage area." It is not clear what this sentence means, and why it is necessary to include it here.

This sentence was used to emphasize spatial extrapolation rather than time series prediction. The sentence has been revised to clarify.

<Sec.1, pp.1-2>

6) Page 3, line 16: "In the above equation..." should read " In equation 7...".

7) Consider using "ionospheric map/model" in places of "ionosphere map/model" throughout the manuscript.

We have changed all the corresponding words. Thanks for the tip.

<Sec.3.1, p.3>, <Sec.1-6>

8) Page 7, line 1: Authors should clarify what previous one-epoch values are referred. What is the interval between successive epochs? Is the interval between successive epochs sufficiently small for previous one-epochs to be safely used? And what happens if there may be no data for previous one, two, three. . .. epochs?

The estimation interval should be the same as the inner ionosphere map input interval. In this research, two-hour interval was used because two-hour interval IGS global map is implemented for the inner map. If a shorter interval inner map is used, e.g. 5 min. SBAS map or real-time GPS-derived map, and then the estimation interval becomes shorter. Our algorithm is not a time-prediction algorithm, as other preceding researches, and the estimation interval is not an important factor to determine the accuracy. It is also because that the estimate more depends on inner ionosphere map than other environmental parameters, e.g. F10.7, Kp etc.

If the inner ionosphere map is complete unavailable, our algorithm should not be used because it is not a prediction algorithm but an extrapolation algorithm. If some points in the inner ionosphere map are not available due to data loss or availability, interpolated data from near grid points replace the data at those points.

If some of environmental parameters, e.g. F10.7 and SSN, are unavailable or delayed, time-predicted value of those parameters can be used. We have already tested prediction of the environmental parameters, but the effect of prediction was not significant because the inner ionosphere map takes a dominant role in the estimation. Sentences have been revised to clarify this aspect.

<Sec. 4, pp.7-8>

9) The authors cite SVM applications to other fields but not a citation on previous ionospheric applications. There have been previous studies on the use of SVM for Ionospheric research. E.g.:
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2010RS004393
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2010RS004633
https://www.ann-geophys.net/31/173/2013/angeo-31-173-2013.pdf

Thank for your tip. Overview of the three papers has been added.

<Sec.1, p.1>, <Ref., pp.14-15>