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Nonlinear Processes in Geophysics
Discussions
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# *Interactive comment on* "Prediction and variation of auroral oval boundary based on deep learning model and space physical parameters" *by* Yiyuan Han et al.

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Dear Reviewer, Thank you for your thorough and very constructive review. we reply to your main points and write a detailed reply in this document.

The main purpose of this paper is to explore the possible relationship between physical parameters and auroral events in a new way. In our previous work, some useful machine learning methods, such as deep learning and generalized regression neural network (GRNN) are used to model the relationship between the IMF and solar wind indexes and the auroral oval boundaries[1]. But we have no certain fact that whether the physical variables except IMF and solar wind indexes can affect auroral oval bound-



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ary. Therefore, we want to obtain some unknown conclusions between more physical variables and auroral oval boundary by using our method in this paper.So, this paper is devoted to designing a new method rather than exploring the specific physical explanations between physical parameters and auroral oval boundary. The more exact physical connections for specific aurora events will be analyzed in future works.

In the manuscript, we design a new nonlinear and trainable mapping model to construct the relationship between auroral oval boundary and complex space physical parameters (including 18 parameters) to discuss the influence of every single space physical parameter on auroral oval boundary sufficiently. The experiment results in our paper show that some space physical parameters play a crucial role to locate the auroral oval position, which is consistent with the conclusion available in most of references. In the other hand, some interesting results have been obtained during the experiment. These conclusions maybe discuss with space physics in the future. In the task of predicting the substorm magnitude and timing, we cannot give an exact conclusion now. Our proposed method can model the relationship between different types of data, such as space physical data and auroral oval images. So, we think the proposed model in this manuscript can predict the substorm magnitude and timing after adjusting the model parameters according to the occurrence conditions and the data forms of substorm. We can give some researches on this problem in the future work. As a summary, our proposed model in this paper give the new way to analysis the relationship between many space physical parameters (such as: PC and SYM/H) which do not mentioned in other literature sand auroral oval boundary.

According to the reviewer comments, the additional two experiments are performed under southward and northward IMF directions conditions respectively according to your suggestion. The experiment results are shown in Table 5(Figure 1 can be considered as Table 5 in this reply document). Whether the northward or southward IMF direction are input to the proposed model, the MAE have marked change in both poleward and equatorward boundaries. Nevertheless, we can observe the more evident

increasement of MAE in equatorward boundaries compared with the MAE of poleward boundaries by using northward IMF direction as the input of our model. Meanwhile, there has an opposite result under southward IMF direction condition. The variation of MAE in poleward boundaries are bigger than equatorward boundaries when the input of our model is southward IMF direction. Therefore, we can know that the northward IMF direction has a great influence on the equatorward boundaries, and the southward IMF direction has a significant effect on poleward boundaries.

According to your comments, We already carefully check our manuscript to correct the typing errors. Details are given below.

(1) Line 3 in Introduction, the sentence 'which can implicit for the coupling process between solar wind, ionosphere and magnetosphere'. was revised to 'which can implicit for the coupling process among solar wind, ionosphere and magnetosphere'.

(2) Line 5 in Introduction,the sentence 'So, the segmentation and prediction for auroral oval boundary is very significant for studying on certain physical events'. was revised to 'So, the segmentation and prediction for auroral oval boundary are very significant for studying on certain physical events'.

(3) Line 12 in Introduction, the sentence 'Variations of the size of polar cap, auroral oval and diffuse aurora are regarded as three independent function variables of AL index (Starkov, 1994(b)).'was revised to 'Variations of the size of polar cap, auroral oval and diffuse aurora were regarded as three independent function variables of AL index respectively (Starkov, 1994(b))'.

(4) Line 15 in Introduction,the sentence 'Sigernes compared methods which proposed by Zhang and Starkov to calculate the size and position of auroral oval using a Kp-based function.' was revised to 'Sigernes used a Kp-based function to calculate the size and position of auroral oval, and compared the Kp-dependent model with methods which proposed by Zhang and Starkov to explain the superiority of his proposed model.'

(5) Line 41 in Introduction, the sentence ‘Sect. 2 describes our proposed algorithm to predict auroral oval boundary in detail.’ was revised to ‘Sect. 2 describes our proposed algorithm in detail.’

(6) Line 3 in section 2, the sentence ‘In the training phase, auroral oval images are usually affected by heavy noise and other interference.’ was revised to ‘In the training phase, auroral oval images are usually affected by heavy noise and other interferences.’

(7) Line 15 in section 2, the sentence ‘The computational processing of RBM and RBF is illustrated by Eq. (1)-(4).’ was revised to ‘The computational processing of RBM and RBF are illustrated by Eq. (1)-(4).’

(8) Line 14 in section 3.1, the sentence ‘According to the effect from other circumstance factors,’ was revised to ‘According to the effect derived from other circumstance factors,’

(9) Line 22 in section 3.1, the sentence ‘Table 1 shows 18 space physical parameters we used in this paper.’ was revised to ‘Table 1 shows 18 space physical parameters which we used in this paper.’ (10) Line 7 in section 3.2, ‘The corresponding MAE is shown in Fig. 3(a).’ was revised to ‘The corresponding MAE are shown in Fig. 3(a).’

(11) Line 12 in section 3.2, the sentence ‘The corresponding MAE is shown in Fig. 3(b), and MAE reaches the minimum when the training error of RBF net-work is 4 magnetic latitudes.’ was revised to ‘The corresponding MAE are shown in Fig. 3(b), and MAE reaches the minimum when the training error of RBF network is 4 magnetic latitudes.’

(12) Line 16 in section 3.2, the sentence ‘To demonstrate the availability of our proposed model, we compare the proposed model with Back Propagation (BP) network (Rumelhart, 1986) and Yang’s model (Yang et al., 2016).’ was revised to ‘To demonstrate the availability of our proposed model, we compared the proposed model with Back Propagation (BP) network (Rumelhart, 1986) and Yang’s model (Yang et al., 2016).’

(13) Line 17 in section 3.2, the sentence ‘The subjective prediction results obtained by

the three method are shown in Fig. 4, circles and squares stand for poleward boundary points and equatorward boundary points which are obtained from the segmented image, ‘ïijŃ’ and ‘×’ marks represent poleward boundary points and equatorward boundary points which are obtained from our prediction model.’ was revised to ‘The subjective prediction results obtained by the three method are shown in Fig. 4, circles and squares stand for poleward boundary points and equatorward boundary points respectively which are obtained from the segmented image, ‘ïijŃ’ and ‘×’ marks represent poleward boundary points and equatorward boundary points respectively which are obtained from our prediction model.’

(14) Line 21 in section 3.2, the sentence ‘it is obviously that our method can obtain the more accurate boundaries than the other two compared methods, where marked by blue rectangle and red rectangle in Figure 4.’ was revised to ‘it is obviously that our method can obtain more accurate boundaries than the other two compared methods, where marked by blue rectangle and red rectangle in Fig. 4.’

(15) Line 6 in section 3.3, the sentence ‘we sort boundary data with respect to the value of all space physical parameters, and divide evenly boundary data into 10 groups.’ was revised to ‘we sort boundary data with respect to the value of all space physical parameters, and divide boundary data into 10 groups evenly.’

(16) Line 15 in section 3.3, the sentence ‘And a correlation analysis experiment is con-structed to study the connection between combination of different space physical parameters and auroral oval boundary.’ was revised to ‘And a correlation analysis experiment is constructed to study the connection between combination of different space physical parameters and auroral oval boundary.’

(17) Line 16 in section 3.3.1, the sentence ‘Such as, Karlson’s observations suggeststhat IMF By component is related to prenoon-postnoon asymmetry of poleward activity (Karlson et al., 1996).’ was revised to ‘Such as, Karlson’s observations suggested that IMF By component is related to prenoon-postnoon asymmetry of poleward activity

(Karlson et al., 1996).'

(18) Line 11 in section 3.3.4, the sentence 'The MAE of boundary position is 1.6076 and 1.4545 respectively when we only use boundary positions at the previous moment to predict poleward and equatorward boundaries. We take this MAE as standard, called S-MAE.' was revised to 'The MAE of boundary position are 1.6076 and 1.4545 respectively when we only use boundary positions at the previous moment to predict poleward and equatorward boundaries. We take this MAE as standard, called S-MAE.'

(19) Line 1 in section 3.3.5, the sentence 'For the sake of analyzing the influence of space physical parameters on auroral oval efficiently,' was revised to 'In order to analyse the influence of space physical parameters on auroral oval efficiently,'

(20) Line 7 in section 3.3.5, the sentence 'The formula of Pearson correlation coefficient is can presented as Eq. (6),' was revised to 'The formula of Pearson correlation coefficient can presented as Eq. (6),'

(21) Line 4 in Conclusion, the sentence 'Those method based is not very suitable for the complex and changeable space physical data.' was revised to 'Those methods are not very suitable for the complex and changeable space physical data.'

(22) Line 9 in Conclusion, the sentence 'we analyze the effect of all 18 space physical parameters on the location of auroral oval boundary based on several statistical and prediction experiments.' was revised to 'we analyse the effect of all 18 space physical parameters on the location of auroral oval boundary based on several statistical and prediction experiments.'

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▪ **Table 5: Pearson correlation coefficient of some space physical parameters from Dec. 1996 to Mar. 1997**

| Parameter name | MAE(poleward/equatorward) |
|---|---|
| IMF | 1.6313/1.4759 |
| IMF(Bz>0) | 1.6365/1.7595 |
| IMF(Bz<0) | 1.7163/1.6193 |
| Solar wind index | 1.6495/1.4877 |
| Geomagnetic index | 1.6569/1.5124 |
| AE, AU, AL, PC | 1.6734/1.5272 |
| Vp, Np, Pdyn, SYM/H | 1.6611/1.4919 |

**Fig. 1.**



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