Summary of Changes

The authors would like to thank the reviewer for the constructive comments. We provide below a detailed account on the changes that we have made in response to the comments that the editor and the reviewers have raised. We have marked the corresponding changes in the revised version in ***red*** color.

Response to Reviewer:

The reviewed manuscript contains some interesting statistical findings based on advanced machine learning methods.

1. My main concern is that the mathematical correlations between the position and size of the auroral oval and some physical variable describing the near-Earth space environment are not interpreted in physical terms. It's been known for a long time that the aurorally oval represents the open/closed field boundary of the Earth's magnetosphere which is responsive to the solar wind driver and reflects the dynamics of the Dungey substorm cycle. A careful discussion of these physical processes in the context of the reported machine learning results is required before this manuscript can be considered for publication.

Author's reply:

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 boundary. 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.

[1] HanB, LianHF, HuZJ. Modeling of ultraviolet auroral oval boundaries based on neural network technology (inChinese). SciSinTech, 2019, 49:531–542, doi: 10.1360/N092018-00227.

2. What do the machine learning correlations show? Do they support or challenge the existing substorm models? Do the enable a more accurate prediction of substorm magnitude and timing?

Author's reply:

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 did not mentioned in other literature sand auroral oval boundary.

3. To make this analysis more informative it would be important to differentiate between the southward and northward IMF directions associated with drastically different solar wind driving conditions.

Author's reply:

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.

Revision:

Table 1: Pearson correlation coefficient of some space physical parameters from Dec. 1996 to Mar. 1997

Parameter name	MAE(poleward/equatorward)
IMF	1.6313/1.4759
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

→

Table 2: The MAE influenced by different combinations of space physical parameters.

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

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.

4. The presentation style is clear but there are multiply typing errors; I encourage the authors to proofread their manuscript before resubmitting.

Author's reply:

Thanks for your kind suggestion. We already carefully check our manuscript to correct the typing errors. Details are given below.

Revision:

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

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

(3) Line 12 in Introduction, '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)).' → '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, 'Sigernes com-pared methods which proposed by Zhang and Starkov to calculate the size and position of auroral oval using a Kp-based function.' →'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, 'Sect. 2 describes our proposed algorithm to predict auroral oval boundary in detail.' →'Sect. 2 describes our proposed algorithm in detail.'

(6) Line 3 in section 2, 'In the training phase, auroral oval images are usually affected by heavy noise and other interference.' →'In the training phase, auroral oval images are usually affected by heavy noise and other interferences.'

(7) Line 15 in section 2, 'The computational processing of RBM and RBF is illustrated by Eq. (1)-(4).' →'The computational processing of RBM and RBF are illustrated by Eq. (1)-(4).'

(8) Line 14 in section 3.1, 'According to the effect from other circumstance factors,' →'According to the effect derived from other circumstance factors,'

(9) Line 22 in section 3.1, 'Table 1 shows 18 space physical parameters we used in this paper.' →'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).' →'The corresponding MAE are shown in Fig. 3(a).'

(11) Line 12 in section 3.2, '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.' →'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, '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).' →'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 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, ' + ' and '×' marks represent poleward boundary points and equatorward boundary points which are obtained from our prediction model.' →'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, ' + ' 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, '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.' →'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, 'we sort boundary data with respect to the value of all space physical parameters, and divide evenly boundary data into 10 groups.' → '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, 'And a correlation analysis experiment is con-structed to study the connection between combination of different space physical parameters and auroral oval boundary.' → '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, 'Such as, Karlson's observations suggests that IMF By component is related to prenoon-postnoon asymmetry of poleward activity (Karlson et al., 1996).' → '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 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.' → '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, 'For the sake of analyzing the influence of space physical parameters on auroral oval efficiently,' → 'In order to analyse the influence of space physical parameters on auroral oval efficiently,'

(20) Line 7 in section 3.3.5, 'The formula of Pearson correlation coefficient is can presented as Eq. (6),' → 'The formula of Pearson correlation coefficient can be represented as Eq. (6),'

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

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