**Atmospheric
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Comment

Interactive comment on "The effects of a solar eclipse on photo-oxidants in different areas of China" *by* J.-B. Wu et al.

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Received and published: 9 May 2011

We thank referee #2 for reviewing our paper and giving valuable comments. The following are our detailed responses to the each comment. For the plain text did not include figures and equations, Please see the attached Supplement PDF, http://www.atmos-chem-phys-discuss.net/11/C1/2011/acpd-11-C1-2011- supplement.pdf

Comment from Referee #2: The authors use the WRF-Chem model to examine the effect of a total solar eclipse on atmospheric pollutants occur over China. The overall idea is excellent and the scientific results and conclusions are presented in a clear, concise, and well structured way. However, the scientific quality, relative to the reproduction of the radiation change due to the solar eclipse, is quite poor and this affects strongly the results and the scientific value of the manuscript. The authors try to re-

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produce the solar eclipse by varying the solar constant and the photolysis rates to the same extent. The variations are introduced by the use of a scaling factor dependent on latitude, longitude and time. Then, they try to validate this hypothesis with downward solar radiation measurements, for which, it is true, the variation during the time of the eclipse is approximately proportional to the obscuration of the sun. However, it has been shown clearly in recent studies (both in ACP, Emde and Mayer(2007), Kazantzidis et al. (2007) and references therein), that the effect of the eclipse on surface irradiance has spectral characteristics due to the limb darkening. According to those studies, the reduction (relative to non-eclipse conditions) in UVB is almost 1.5 higher than UVA and visible. This effect should be introduced in the WRF-Chem radiation scheme, since it affects significantly the photochemical calculations of this study. In this case, most of the scientific work and analysis should be redone. So, I recommend the rejection of the manuscript.

Reply to Referee #2: The authors thank the Referee for reviewing our paper and giving valuable comments. In our previous manuscript, the reproduction of the solar eclipse is introduced by the use of a scaling factor dependent on latitude, longitude and time. However, some previous studies (Emde and Mayer, 2007; Kazantzidis et al., 2007 and references therein) showed that the effect of the eclipse on surface irradiance has spectral characteristics due to the limb darkening, which leads to more pronounced decrease in the radiation at the lower wavelengths.

Therefore, it is more precise to take the limb darkening into account, and the mathematics of the limb darkening and its effect on different wavelengths during the solar eclipse are introduced in Section 1 of this reply. The authors decided to study the sensitivity analysis of limb darkening effect on surface ozone using a box model (Section 2), which is also added into the revised manuscript. Finally, we will also conduct the WRF-Chem simulations with a corrected scaling factor which is dependent on latitude, longitude, time and wavelengths: J = J * fac(lat,lon,time,wavelength) The reproducing the solar eclipse in the WRF-Chem model was solved by varying the solar radiation

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and photolysis rates according to the obscuration of the sun, which alters by different grid point and time. For example, the obscuration of the sun in each grid point is proportional to the distance from the center of the total eclipse at a given time. Since the moon's umbral shadow moved with a specified velocity on earth, the obscuration in each grid point needs to be rescaled in the next time step. In addition, the limb darkening effect is introduced in this scaling factor, which shows that shorter wavelength radiation reduced slightly more at a given obscuration. The renewed discussion can be referred to the revised manuscript.

1. Mathematics of limb darkening During different times of an eclipse, the disk of the moon covers different parts of the limb and the center of the sun. The radiation from the limb of the solar disk is less intense than that from the centre. Moreover this limb darkening is spectrally dependent. Thus the spectral composition of the irradiance of the sun changes during the eclipse (Emde and Mayer, 2007; Kazantzidis et al., 2007; Koepke et al., 2001). E1-E6 (please see supplementary PDF file)

Fig. 1a shows the decrease in Inorm with decreasing X due to obscuration of the sun covered by the moon. The bold grey line represents the normalized intensity of a hypothetical sun without limb darkening (noLD). Inorm(λ) is wavelength dependent because of limb darkening. These wavelengths are chosen to cover the spectral range of interest. 310nm is important for the photochemical processes of O3 and NO2. The wavelength 550nm is given as a standard wavelength for visible light and 1500nm is shown as an example for a wavelength of the infrared spectral range. Compared to the line of no limb darkening (noLD), the normalized radiation for each wavelength (Inorm(λ)) enhances when the distance of the centers of moon and sun is larger than 0.5 ($|X|>0.5$). During that time when limb of the sun is covered by the moon, the brighter central region of the sun still emits large radiation. During the central parts of the sun obscured by the moon ($|X|<0.5$), Inorm(λ) reduces because larger radiation in these region is blocked.

Fig. 1b presents the spectral dependence of the solar radiation during the eclipse when

compared to the case of no limb darkening (noLD), which is calculated by formula: (E7) (please see supplementary PDF file) It is obvious that shorter wavelength is affected more by limb darkening effect. The reduction of the radiation is more significant when close to the central part of the eclipse. When $|X|>0.9$, the Inormλ is reduced by more than 60%, 30% and 10% at 310 nm, 550nm and 1500nm respectively.

(please see supplementary PDF file)

Fig. 1 Normalized radiation as function of X, the distance of the centres of moon and sun, during eclipse for different wavelengths (a); Effect of limb darkening as a function of X for different wavelengths

2. Model uncertainties from limb darkening effect As mentioned in Section 1, the spectral dependence of radiation due to the limb darkening of the sun becomes relevant during a solar eclipse. It is necessary to investigate how the limb darkening affects the surface ozone. A CBM-Z chemical box model (Zeveri et al., 1999) is used to carry out three sensitivity experiments, which is depicted in table 1.

Table 1 description of sensitivity experiments (please see supplementary PDF file)

case description Non-Eclipse Normal radiation according to solar zenith angle Eclipse-LD Reduced radiation with limb darkening effect (black line in Fig. 1a) Eclipse-noLD Reduced radiation without limb darkening effect (grey line in Fig. 1a)

It is known that 310 nm is important for the photochemical processes of O3 and NO2. And the photolysis rate is directly influenced by solar radiation at this wavelength. Therefore, the variation of photolysis rate can be factored by the reduction of Inorm310nm showed in Fig. 1a. It should be noting that Fig.1a presents half part of an eclipse, and there is another part of eclipse which denotes that the moon leaves the sun gradually. Fig. 2 shows the Photolysis rate of ozone (JO1D, s-1) in three sensitivity experiments during a solar eclipse event. The JO1D value in Non-Eclipse experiment displays steadily increase in the morning time, while Eclipse-LD and Eclipse-noLD ex-

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periments reveal reduction during the eclipse period. The difference of JO1D between Eclipse-LD and Eclipse-noLD is the same extent as Inormλ between 310nm and noLD (Fig. 1a). In Kazantzidis (2007)'s work, also cited by the Referee, Radiative transfer model results were used for the computation of a correction for the total ozone measurements due to the limb darkening. This correction was found too small (less than 0.01%) to explain the large decrease in total ozone column derived from the standard Brewer measurements. Here we confirm this find by the ozone concentration from the box model (Fig. 3). Ozone concentration in Non-Eclipse run shows steady increase during the solar eclipse period, while Eclipse-LD and Eclipse-noLD results present a slightly decrease. It is worth-noting that these two lines (Eclipse-LD and Eclipse-noLD) are almost the same, with more pronounced decrease in Eclipse-LD experiment. The effect of limb darkening on surface ozone is less than 0.5%. Although the effect of limb darkening on shorter wavelength is larger (Fig. 1b), the absolute difference of reduced solar radiation between short and long wavelength is small (Fig. 1a). This small perturbation leads to limited change in surface ozone between Eclipse-LD and Eclipse-noLD experiment. Therefore, it is concluded that the effect of limb darkening on surface ozone is too small to explain the large decrease in surface ozone during a solar eclipse event.

(please see supplementary PDF file)

Fig. 2 Photolysis rate of ozone (JO1D, s-1) in three sensitivity experiments.

(please see supplementary PDF file)

Fig. 3 Ozone concentration (ppbv) in three sensitivity experiments.

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Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/11/C3009/2011/acpd-11-C3009-2011-supplement.pdf

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 2473, 2011.

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