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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Attenuation of global ultraviolet and visible irradiance over Greece during the total solar eclipse of 29 March 2006" *by* A. Kazantzidis et al.

A. Kazantzidis et al.

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Response to referee 1

We thank the referee for his/her helpful suggestions and constructive remarks. We have accordingly modified the attached version. The introduced changes are explained below.

Comment of the referee: [For example, why does the 3-D model fail to reproduce the overturned ratio at 305/380 in Fig 5? Neither is it made clear why the two models were set to simulate the eclipse. Was it just a challenging test for the models, or to prove that 3-D is better than 1-D, or to try to provide an explanation for the observations?]

It is true that the 1-D (shown in figure 5) and the 3-D model (discussed in the relevant text) fail to reproduce the overturned ratio at 305/380. The effect is similar at all three sites, but the interpretation of this observation remains a challenge. Unfortunately, no ozone profile data were available, but strong experimental evidence that there was an oscillation in the total ozone column is provided by Zerefos et al. (Atmos. Chem. Phys., 7, special issue on eclipse 2006, 2007). According to that study, the cooling of ozone layer in the stratosphere by the supersonic travel of the moon shadow during an eclipse constitutes a source of gravity waves propagating both upwards and downwards. It is also evident that our observation should be related with the strange ozone behavior that was also reported in other relevant studies. So, the authors believe that there is still a great challenge for future research. The text in the abstract and the conclusions of the revised manuscript has been modified, in order to point out that this is still an open field. Additionally, the study of Zerefos et. al., is discussed in paragraph 5.2 of the revised manuscript. As far as concerned the use of the two models, the authors believe that the availability of several instruments in close proximity to the path of the umbral shadow provide a challenging test for the models. Specifically, the formulas adapted by Koepke et. al., (2001) for the 1-D model have been compared with measurements during the eclipse of August 11, 1999, under cloudy conditions. In addition, it is the first time that 3-D model results during a solar eclipse are compared with measurements. The text in the abstract, introduction and conclusion paragraphs has been modified in the revised manuscript, in order to explain our intention.

Comment of the referee: [The use of % is sometimes confusing as it is used in several different ways in the manuscript: for sun coverage (text), sun visible (figures), difference between measurement and model, and model capture of the eclipse effects. a) can terminology in text and figures (eg Fig 2-6) be made consistent b) when using % differences for model - measurement comparison of effects observed changes should be compared, not resulting absolute values. For example the changes in ratios of different wavebands (P13486 line 6) are said to agree within 10% yet the model only captures half the change observed. There are many instances of subjective quality

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statements e.g. P 13477 paragraph lines 9-25 contains quite well,good agreement and more accurate& without providing any quantitative benchmark to define what is good. Other examples can be found on P13476 line 14 an agreement with measurements P13480 line 1 considered negligible. Please quantify.]

The revised manuscript has been modified according to the suggestions of the referee: a.Apart from the abstract, we use only the visible part of the sun& to make the terminology consistent. b. The text was revised in order to examine the model differences relative to the observed changes and to point out that the model captures only the half of the observed change. c. The qualitative statements have been replaced with numbers. Apart from the abstract and conclusion paragraphs, the following paragraphs were also modified: Paragraph 3.1: The maximum change in the solar zenith angle....at all other NILU-UV channels Paragraph 4.1: The agreement between measurements and modeled values....become significant. Paragraph 4.2: The differences between modeled and measured..observed also for PAR. Paragraph 5.1: For both wavelength regions the agreement...only the half of the observed change. Paragraph 7: For the 380nm channel, the agreement...modeled and the measured values is within 40%.

Response to the specific comments of the referre:

1. The word radiometers has been replaced with the word actinometers.

2. In our study we used the model-calculated values by Emde and Mayer (2007) during totality in the 300-500 nm wavelength region. The full width at half maximum of the actinometer UV channels is approximately 10nm. As a result, there was no way to compare our measurements with the model estimates for the first channel (305nm). As discussed also in the manuscript, the data for this channel close to totality were excluded, as the signal reached its minimum. In addition, the current version of model calculations is unable to simulate the whole visible spectrum and as can be seen in Emde and Mayer (figure 11), the decrease of solar irradiance during the totality is wavelength dependent also in this wavelength region. At the end of paragraph 7, a

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sentence has been added to state the inability to perform any comparison in the visible region. As a result, we compared our measurements with the model results for the rest of the NILU-UV channels, as discussed in paragraph 5. We also modified the manuscript in order to quantify the difference between model estimates and measurements. The following document was added: For the 380nm channel, the agreement between the model calculations and the measurements just before the beginning of totality is within 10%. The measured irradiance decreases more rapidly during totality but the percentage difference of the two radiative quantities close to the time of the eclipse maximum is less than 5%. After the end of totality the model overestimates the irradiance by ˜20%. Similar results were obtained also for the 340 nm channel (not shown here). However, for the 312 nm channel the model estimates during totality are three times lower, most likely because of the increasing noise in the measurements during the totality (the measured raw counts were only 30% higher than the dark current), but also because of the possible uncertainties in determining the spectral response of this channel. Close to and after the end of totality the agreement between the modeled and the measured values is within 40%.

3. No, the lamp is 1000 W!

4. The revised manuscript was modified in order to clarify that in all stations the ozone values ranged from 285 DU to 355 DU.

5. The revised text was modified according to the suggestions of the referee.

6.The sentence has been deleted.

7-14. The revised text was modified according to the suggestions of the referee.

15. According to Bernhard et al. (2005), the agreement between the NILU-UV channel irradiances and spectral measurements is within ś5% for solar zenith angles smaller than 85 degrees. As far as concerning ozone, the uncertainty is 0.3% for clear skies and solar zenith angles smaller than 60 degrees (Dalhback, 1996). These numbers

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have been added to the relevant text of the revised manuscript (paragraph 2,Instrumentation and data).

16. The paragraph has been excluded from the revised manuscript. In the revised manuscript of Kazadzis et. al.(2007), only the spectral differences between model estimates and measurements are discussed.

17. The revised manuscript has been modified according to the suggestions of the referee.

18. The reported differences in total ozone at Kastelorizo and Nicosia correspond to measurements performed before and after the end of the eclipse. In contrast, the behavior of 305/380 irradiance ratio, described at this part of the text, corresponds to high eclipse percentage conditions. As it can be seen in figure 6, at all sites the measured total ozone was decreased for high eclipse percentages, so the 305/380 irradiance ratio should be increased. The sentence was rephrased to clarify this point of discussion.

19. The limb darkening effect was not applied to the derived ozone. It was just used in model calculations in order to examine the possible impact of limb darkening on total ozone calculations from the 305/320 irradiance ratios. The methodology to derive the total ozone values and the model-calculated limb darkening effect is discussed more extensively at the same paragraph of the revised manuscript. The following sentences were added: a. The total ozone values, were determined by comparing a calculated and measured irradiance ratio at two channels with different ozone absorption, according to the methodology proposed by Dahlback (1996). The calculations were performed for cloud-free conditions and a look-up table was created to relate the solar zenith angle and the irradiance ratio to total ozone. b. The calculation of total ozone column performed also during the eclipse. In order to examine the effect of challenging radiative conditions, the measured irradiance ratio was not corrected by the limb darkening effect (it was estimated separately from 1-D model calculations) and the look-up table

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was not altered.

20. As mentioned in previous comment, the sentence has been rephrased, in order to present clear our point: the limb darkening effect, as adapted from Koepke et. al. (2001), can explain only partly the measured variations in total ozone values during the eclipse.

21. The revised manuscript has been modified according to the suggestions of the referee.

22. The difference between the midlatitude and the tropical profiles (scaled to the same total ozone value) is mainly at the height of the ozone maximum. The first one was considered more appropriate for Kastelorizo (36.15o N). The use of a standard ozone tropical profile (usually applied for sites below 30o N) just helps to provide a short sensitivity analysis about the possible impact of profiles in model calculations. Unfortunately, no ozonesondes were performed at the eclipse day in Greece or generally in the vicinity of the moon shadow.

23. In both 1-D and 3-D model calculations we used the spectral response of our NILU-UV actinometer at Kastelorizo. In this case, we could diminish this part of measured uncertainties during totality. For all other instruments, the wavelength of the spectral response maximum differs by less than 0.2nm at all UV channels, while the full width at half maximum in identical. In figure 4 from Bernhard et al. (Optical Engineering 44(04), 041011, 2005), you can examine the effect on solar irradiance for a much larger difference in the spectral response maximum wavelength (0.5 nm): even at 305 nm, the difference is less than 5% for the same interval of solar zenith angles (31-44 degrees). Of course the irradiance conditions during the eclipse are not the same. But also in this case, we found out 1% difference when applying the maximum expected shift (0.2nm) in 1-D model calculations of 305nm channel irradiance. Such a difference can be considered negligible compared to the reduction of irradiance due to the eclipse.

24. Measurement uncertainties have been quantified in the revised manuscript (please

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refer to our answer to comment 15). The uncertainty in computed spectral irradiance is estimated to within 2% for cases with small solar zenith angles (van Weele et al., 2000, also added in paragraph 3.2). As mentioned also in relevant studies (e.g. Mayer and Kylling 2005), the needed assumptions in model input parameters and their influence on the results must be kept in mind while validating the models against measurements. In our study, it is puzzling to quantify the overall uncertainties, since there is no information about the extent of variability of the model input parameters during the eclipse. This is the reason that we performed the double normalization when comparing the 3-D model estimates and the measured data during totality. In that case, those uncertainties were diminished and the variability of irradiance was examined assuming that the atmospheric conditions remained stable for a short time period.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 13475, 2007.