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Interactive Comment

Interactive comment on "Observations of convective clouds generated by solar heating of dark smoke plumes" *by* L. Klüser et al.

Anonymous Referee #1

Received and published: 14 March 2008

Review of Klueser et al., 2008

The manuscript by Kluser et al., presents satellite observations of convective clouds that form over a desert area along a smoke plume that emerged from Lebanese burning oil tanks. MSG and MODIS observations from 17 July 2006 are used to characterize the clouds and their evolution. It is suggested that the thermal contrast at the edge of the smoke plume that results from the solar heating of the light-absorbing smoke particles is responsible for the cloud formation.

The manuscript is well written and the observations are well presented. Several lines of evidence are used to show that the clouds that form along the smoke plume would not have formed without the presence of the smoke plume. While this evidence rather convincing I have some objections regarding the mechanism of cloud formation; also the interpretation of the satellite data regarding the impact of the smoke plume on surface temperature seems inadequate. In my view, this requires some revisions. In addition, it would be helpful and enlightening to include information on the meteorological situation, e.g., by including a synoptic map and/or a vertical sounding.

Overall, this manuscript presents a nice example of one of the manifold aerosol-cloud interactions and I recommend publication of the manuscript after the following specific comments are incorporated.

Specific Comments:

- Title: The title is slightly misleading since the term ‘convective clouds’ is often used in association with deep convective clouds and thunderstorms. While the title is technically correct, I suggest to be more specific and to add ‘shallow’ before ‘convective clouds’ so that the title than reads:

  Observations of shallow convective clouds generated by solar heating of dark smoke plumes

- Figure 3, caption: ‘reflactance’ should read ‘reflectance’

- Page 553, line 18ff: The 10.8 mum brightness temperature of the smoke plume is reduced by about 10 K compared to cloud free days. The authors conclude that this goes along with a ‘significant reduction in surface temperature below the smoke plume due to the solar heating of the smoke’.

  To my understanding, the 10.8 um-brightness temperature is determined by the atmospheric temperature of the layer that mainly emits the thermal radiation. When clouds are presented, the brightness temperature represents the cloud top temperature. In the case of a thick aerosol layer like the smoke plume investigated here, the brightness temperature likely represents the temperature of

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the top of the smoke plume. Hence, my interpretation of these observations is that the top of the smoke plume is about 10 K colder of the surface and probably reside about 1 km above the ground. The interpretation of the brightness temperature as the surface temperature below the smoke plume implies the assumption that the smoke plume does not interact with the 10.8 um thermal radiation. If this interpretation is intended this assumption should be stated and its validity should be shown.

It is feasible to assume that the smoke plume, by absorbing and scattering of solar radiation, has led to a reduced surface temperature. However, I am skeptical that the impact of the smoke plume on surface temperature can be determined with satellite observations under these conditions. Please comment and modify/extent the statement in the manuscript.

- Figure 5, caption: Remove 'again' from line 2 of the figure caption. Following the previous comment I suggest to remove the last sentence of the figure caption.

- Page 554, line 21: '13:00' should read '13:45'

- Page 555, second paragraph: MODIS data is used fort further analysis of the cloud properties. I suggest to add the visible images obtained by the two MODIS instruments from this scene, these are available at http://rapidfire.sci.gsfc.nasa.gov, subset AERONET_SEDE_BOKER, at least the link should be mentioned. In addition, it would be interesting to have some information on the aerosol retrieval by MODIS. What was the aerosol optical depth of the smoke plume? I believe that this data is also available.

- Figure 8, caption: Include information on the satellite and the time of the scene in the figure caption.

- Figure 9: The ranges of the x and y-axis should be adjusted to the values shown in the figure. It could be added that here the brightness temperature is used as a

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measure of cloud top height.

- Page 555, lines 17, 18: Please be more quantitative and give numbers for the effective radius of the droplets and the limit of the retrieval algorithm such that the sentence then reads:
  'These data first of all reveal extremely small cloud droplet effective radii below ??? for all cloud covered pixels, actually being at the lower limit of the retrieval algorithm of ???.'

- Page 555, line 18 ff: The effective radius of the cloud droplets is determined by the number of cloud droplets and the liquid water content (LWC) (see e.g., Reid et al., JGR, 1999). While it is feasible to assume that the air that is fed into the cloud is highly polluted from the smoke, it is equally feasible to assume that the air is relatively dry, resulting in a low LWC. Both assumptions can explain the relatively low effective radius of the cloud droplets. Please comment and add a statement regarding the possible impact of the LWC on the low effective radius.

- Page 555, line 21: It does not seem to be straight forward to derive 'cloud base temperatures' from MODIS observations. Usually cloud top temperatures are derived, please explain how cloud base temperatures are determined or modify this statement.

- Page 555, line 24: The statement that the clouds remain below the freezing level should allow to classify them as 'shallow convective clouds'.

- Page 556, lines 9 -11: It is not stated how a reduction of the surface brightness temperature under the smoke plume by 12 K can be derived from MODIS, please specify. The brightness temperature of the smoky pixels is certainly lower than that of the surrounding pixels, but this can be attribute to the fact that MODIS probably 'sees' the elevated smoke layer at a lower temperature than the surface.

- Page 556, lines 11 ff: I agree that the reduced reflection of solar radiation indicates solar heating of the smoke plume, which should result in a rising motion of the smoky air. However, it is not clear why the thermal contrast at the edge of the smoke plume should favor the triggering of convection. Please specify.

- Page 556, line 18: 'The smoke seems to be darkest around the clouds.' Can this statement be quantified, e.g., by the use of MODIS derived aerosol optical depth or by a comparison of the reflectances for pixels around the clouds with background pixels.

- Page 556, line 23 ff: The statement '... convective clouds grow regardless of an environment, ... ' seems to suggest that there is no impact of the environmental conditions on the growth of convective clouds. This is not that case here, since the environment prevents the clouds from developing into deep convective clouds. Please modify the statement.

- Page 556, line 24: replace 'convection' with 'cloud formation' so that the sentence now reads: '... in which cloud formation without the presence of a smoke plume...'.

- Page 557, line 12/13: Please indicate that also a low LWC can explain the low effective radius:
  'The small effective droplet size is consistent with a very large number of cloud droplets and/or a low liquid water content within the observed clouds.'

- Page 557, line 15ff: Cloud base temperatures were not determined by MODIS. How is the boundary layer height determined? Maybe the clouds remained within the boundary layer?

- Page 558, line 2: Maybe the reference Kaufman and Koren, Science, 2006, could be included here.

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- References: Please check again the references, there are some references in the reference list that do not appear in the text, e.g., Trentmann et al., 2003, Twomey, 1977.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 549, 2008.

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