

Interactive comment on “Constraining the Twomey effect from satellite observations: Issues and perspectives” by Johannes Quaas et al.

Anonymous Referee #3

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This overview paper is a pretty substantial and concise overview of Twomey effect diagnostics from space, principally with passive solar observations. The paper is generally well-written (save a few passages – something not unexpected given the many co-authors and the unavoidable mixing of styles) and breaks down the problem in an intelligent and intuitive manner. The heart of the paper is eq. (4) which is then further recast as eq. (5). These equations indicate that assessing the strength of the Twomey effect rests on being able to predict the change in cloud droplet number concentration given an anthropogenic CCN perturbation. The latter is not examined; rather the paper focuses on whether the sensitivity of droplet concentration to changes in CCN can be inferred from space observations. The issues investigated are whether aerosols (and what aerosols in terms of vertical location) can stand-in for CCN and at which

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level in the cloud the knowledge of the droplet concentration is relevant to calculate the Twomey radiative perturbation. Given the nature of the paper, there is really no original research, but there is plenty of good insight. The paper lacks visual support: there are only three figures in 18 pages. To me at least, it seemed as if the paper loses steam starting in section 4 when text appears to suffer from deteriorating clarity and appears to be more hastily written. But all in all, this is a very noteworthy effort that does not need much of a revision before it becomes a reference to be frequently visited by the aerosol-cloud interaction community.

Some remarks/suggested edits:

Line 10 and many instances thereafter: “vertical wind” does not seem the right term; rather people traditionally use the term “updraft velocity”, or, given the convention of this paper, “updraught velocity”.

Line 11: “10s”, this read like 10 seconds to me, so better write explicitly “tens”.

Line 21: “the impossibility” (of retrieving base CCN): Well, some would disagree, and the paper itself does cite Rosenfeld et al. (2016) who claim that such retrieval is possible. See line 289.

Line 53: Cloud horizontal extent is actually irrelevant, if the quantity of interest is cloud albedo. Cloud fraction becomes relevant only when the dependences of the Twomey effect on spatial scales is discussed and then only when mixtures of clear and cloudy skies are considered, namely the Twomey effect is expressed in terms of the cloud radiative effect.

Line 54: “ a_c is a monotonic function of N_d ”: only when the cloud condensate is constant.

Eq. (2): A derivative of absolute a_c change with respect to a relative (logarithmic) N_d change is shown, while eq. (1) is expressed in terms of relative changes for both quantities. It may make sense to keep these consistent. See also line 81.

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Line 66: SOLAR zenith angles.

Lines 75-79: N_d is also a function of L (you say that actually in line 323), so I don't understand the argument here, which is fundamental for insisting that Twomey effect studies are conducted in terms of N_d (not a directly retrievable quantity) and not r_e (which is directly retrieved). Changes in L can be distributed as both droplet size and droplet number changes, no? See also lines 435-436 about the need to stratify by L when using r_e .

Lines 169-171: Need to clarify that this is the case for passive SWIR observations. Lidar retrievals are discussed elsewhere in the paper.

Line 200: I suggest "become less representative of aerosol variability".

Line 201: To be consistent with elsewhere in the text: "updraughts".

Lines 271-272: It is implied here that AI is routinely available from space. Is it? For example, MODIS dark target provides AI only over ocean. Is it reliably retrieved? Fig. 2 excludes the land, probably because of this exact unavailability of AI over continents.

Line 284: The MERRA-2 aerosol re-analysis is also another popular product. Lates in lines 287-288, it is not clear how one can evaluate re-analysis aerosol, especially underneath cloud. One has to use observations that are not part of the assimilation process.

Line 294: I suggest "derivations of supersaturation".

P. 12 discussion on N_d retrieval uncertainties: The discussion seem to suggest that higher resolution measurements are needed to reduce cloud heterogeneity effects, yet the retrievals should eventually be coarsened anyway to reduce the random error.

Lines 359 and 362: Deriving cloud base and cloud physical thickness is of course one of the most difficult problems in space-based remote sensing. Lidar can be useful only when the clouds are optically thin (optical thickness below 3-4). So, I wouldn't count

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too much on space-based lidars for many of the clouds that are relevant to the Twomey effect.

Line 401: "beta_hat is smaller than unity". Earlier, line 87, it was established that beta is smaller than unity. No range was given for beta_bar, but presumably the same implies. Do the authors then mean to say in line 401 that beta_hat is smaller than beta_bar?

Line 438: conditions cannot become small, so the authors need to rephrase.

Line 445: I suggest you say "closer to ~50 km scales".

Section 6: I found this section about confusing, but I think mostly because of my unfamiliarity with the "regression dilution" concept and the ways its impact is assessed. The term does indeed exist and describes the biasing of the regression slope towards zero values, but you may want to provide a brief definition and description. For people who are familiar with this bias tendency this section may make more sense. Please revisit and ensure that you provide maximum clarity to the uninitiated.

Lines 473-474: "the impossibility to retrieve it in cloudy skies". This is a sweeping statement which need some qualifiers. Yes, you can't probably retrieve aerosol under clouds in most situations, but with lidar it is possible both above and below clouds for certain clouds. Also you can retrieve aerosol between individual clouds of a cloud field from both passive and active. Such a cloud field is still "cloudy skies".

Line 480: I suggest "in addition to retrievals".

Line 486: I suggest "relates imperfectly to the N_d ".

Line 487: You mean sensitivities less than one? I don't understand as it is currently written.

Line 504: I suggest "quantification supported by data".

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