Interactive comment on "Long-term aerosol-mediated changes in cloud radiative forcing of deep clouds at the top and bottom of the atmosphere over the Southern Great Plains" by Hongru Yan et al.

Anonymous Referee #1
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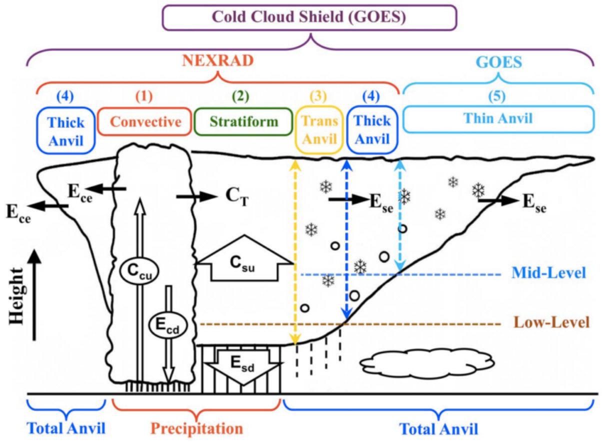
In this work the authors provide more evidence to the cloud invigoration effect. They are presenting a thorough analysis of more than 10 years using a combination of surface and satellite measurements supported by reanalysis data. They also estimate the radiative forcing of the effect. Although the variety of data sets is impressing, essential information on the analysis is missing.

We have added more analyses about the invigoration effect and meteorological influences on the invigoration effect as suggested by the reviewer.

First of all the authors should provide information on the type of clouds and the typical meteorological states over the SGP site. Examples of essential questions waiting to be answered are: Is it only convective clouds, or do stratiform clouds form there? Do they separate frontal from post-frontal systems? Do they combine clouds from many different years and seasons? Do they account for air masses that come from different directions?

This study is a follow-up study of Li et al. (2011, Nature-Geosci) that revealed the phenomenon of the aerosol invigoration effect (AIV). This paper attempts to quantify the radiative effects of the AIV. Both studies deal with deep convective clouds (DCC), while this study further divides DCC systems into deep core, moderate stratiform, and thin anvil parts by virtue of GOES satellite-retrieved COD. As such, the same approach is followed to identify DCCs based on ground-based retrievals of cloud top and bottom height and temperature. Once a DCC (core) is identified, GOES satellite data are used to define the associated stratiform and anvil clouds, which is illustrated in the figure below from Feng et al. (2011).

Given the volume of data collected over a 10-year period, it is not practical to classify weather regimes in terms of frontal activities and relative locations with respect to the location of a front to decide whether a DCC is part of a frontal or post-frontal system. This could be done for a handful of case studies though. As far as the AIV is concerned, a front may not matter as much as known factors such as convection strength, wind shear, and humidity. The influences of these variables were investigated to the extent that could be done *with the observation data available as shown in Figure2, in addition to those described by Li et al. (2011).*



The authors use GOES data in 4 km resolution. It is not clear how many pixels they require to define a cloud. Even if they take one (which is not a good practice in remote sensing data analysis), it means that clouds sized below 4by4 km will not be analyzed. A 4by4 km cloud is not small and in case of convective clouds such one-pixel clouds can be 3-5 km thick. In some conditions such clouds could reach the freezing level. Therefore I would have doubts regarding the quality of such an analysis for warm clouds. The authors should note that satellite analysis is always biased to large clouds.

We have added statements about this limitation in the revised manuscript.
Yes, GOES data has a resolution of 4 km which is too coarse to resolve clouds, especially warm cumulus clouds. However, this study is concerned with large DCC systems like those shown in the schematic plot above. As stated before, DCCs are identified using ground observations, while cloud amount and the TOA radiation budget are obtained from the GOES satellite. GOES cloud products are only used to inspect the structure of clouds (see Fig. 6). Dong et al. (2002) evaluated the GOES cloud products against surface and aircraft data and found that they have sound quality.

It is not clear why the authors have not used MODIS (at least as supporting information), which have more reliable retrievals and higher resolution.

MODIS data was not used because multiple daytime measurements are needed to determine daily mean radiative forcing values. The MODIS is onboard a polar-orbiting satellite that has only one daytime and one nighttime overpass over a particular location, while the GOES provides samples every 30 minutes. The diurnal variation in SW CRF is governed by both varying SZA and diurnal changes in DCCs. This necessitates the use of data from the GOES to estimate the diurnal mean AMCRF, which was done in this study.

The authors should explain more about the paper‘s statistics. How many shallow clouds?

What are their definitions to the cloud subsets? Having a GOES image every 30 minutes, they probably sampled many of the clouds more than one time during different stages of their development. Will it affect their results?

When both ARSCL and GOES data are available, the total number of cases is 22, 820. After constraining the data to single-layer clouds with base temperatures greater than 15°C, the number of cases dropped sharply to 861. The number of samples further decreased when limiting the CTT to greater than 0°C: 195, 240, and 81 samples corresponding to CN ranges of 0-2000 cm^{-3}, 2000-4000 cm^{-3}, and 4000-6000 cm^{-3}, respectively. This information is added to the revised manuscript, per the reviewer's suggestion.
Because our estimates of AMCRF are for the column surrounding the ARM central facility with a maximal horizontal domain of 20 km x 20 km, samples separated by 30 min should be independent on average, based on the mean speed of cloud movement over the area (Dong et al., 2002).

Acronym usage is very intensive and it makes the paper's points difficult to follow.

The use of acronyms in the revised manuscript has been changed so that the text reads more easily.

They summarize empirical observations without explaining their physics. Why invigoration is mostly shown in moist environment (competition with entrainment)? Why warm base and mix or cold tops?

As the reviewer suggested, we have added explanations in the revised manuscript. Note that the physics behind the empirical observations is not the thrust of this study.
In a moist environment, there is an ample supply of water vapor available for condensation to generate more latent heat to invigorate convection.
Under weak wind shear conditions, the increase in condensational heating can be larger than the increase in evaporative cooling and/or entrainment as the amount of aerosols increases, leading to an increase in net latent heat release and then stronger convection. With strong wind shear, the increase in evaporative cooling is always larger than the increase in condensational heating with increasing aerosol loading, leading to the suppression of convection.
For a warm-based cloud, an increase in aerosol loading reduces the cloud droplet size and suppresses rainfall. More cloud water can then be lifted by updrafts to form more mixed-phase regions which invigorate convection.

Finally, the introduction is not exact. It uses most of the right keywords and many of the important references but not in their precise context. For example, Andrea 2004 did not deal with anvils at all. Anvils were discussed in Koren et al, 2010 (which they cite). They could find few physical insights in the review of Tao et al, 2012 (which they cite) and new ideas in http://onlinelibrary.wiley.com/doi/10.1002/2013JD020272/abstract

We have improved the introduction. Guidance to suggested readings is appreciated.