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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Exploring the differences in cloud properties observed by the Terra and Aqua MODIS sensors" *by* N. Meskhidze et al.

N. Meskhidze et al.

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We would like to thank Dr. Wood for thoughtful comments. We have done our best to address each of the points as detailed below.

1. My comment concerns the interpretation of the key result of this paper, namely how the magnitude of the morning-afternoon differences (Terra-Aqua) in cloud cover and cloud optical thickness increases with aerosol optical thickness for the Peruvian stratocumulus region. I do not dispute the result itself, but the interpretation that these findings could represent aerosol indirect effects fails to acknowledge the hypothesis that correlations between meteorology and the spatial distribution of aerosols can explain the results without invoking aerosol indirect or semi-direct effects. Dry heating on the Andes cordillera generates a powerful diurnal gravity wave that results in a strong diurnal cycle of subsidence right along the coast of Chile and Peru (Garreaud

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and Muñoz 2004) which results in extremely powerful and persistent afternoon clearing in the coastal strip out to several hundred kilometers offshore. Examination of the MODIS aerosol product shows that this is also the region with the highest aerosol optical depth, which is not surprising given that industry in the coastal strip is a strong source of aerosol particles and aerosol precursor gases such as sulfur dioxide. Strong subsidence in the afternoon from the gravity wave response leads to particularly thin daytime clouds, and so strongly diurnally varying clouds and high aerosol optical depth are connected primarily via dynamical processes that control both the aerosol transport and the dynamical cloud forcing. The results in Figure 3 would be a direct consequence of such a covariation. Thus, there is no need to invoke aerosol indirect or semi-direct effects to explain the results. Of course, one cannot rule out a contribution from these processes, but the method used in this paper is not appropriate for isolating these effects. Similar correlations are likely to exist in most of the subtropical stratocumulus regions where pollutants decrease with distance downstream from the coastal regions.

We totally agree. Manuscript did not include detailed discussion of climatic effects that are known to be controlling factors for diurnal cycle of marine stratocumulus. As the results shown in the manuscript represent averages over 7 years, it was anticipated that day-to-day weather variations - which can be effectively considered to be stochastic "white noise"; in this context - should not produce systematic bias that could influence the conclusions. However, if (as you correctly pointed out) morning-to-afternoon variations in cloud amount and liquid water are associated with regular meteorological conditions (such as regular and marked subsidence in subtropical southeast Pacific), untangling the responses of clouds to regional-scale variations in aerosol abundances from dynamical forcing becomes increasingly difficult. This is particularly challenging for remotely sensed studies, since air masses that exhibit different aerosol properties usually have different histories and are invariably subject to covarying meteorological conditions. Figure 3 in the revised manuscript suggests that days characterized by elevated AODs may also be associated with enhanced afternoon reduction of clouds. To examine the potential contribution of aerosols and dynamical forcing, we have se-

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lected a stratocumulus cloud region off the coast of Peru. Previous studies show, that off the coast of Peru and northern Chile vertical velocity at 850 mb level is a good indicator for the diurnal cycle of subsidence (Garreaud and Muñoz, 2004; Bretherton et al. 2004) and therefore large-scale vertical pressure velocity (Pa/s) at 18 UTC (closest to the Aqua overpass) was chosen for as a proxy for the subsidence in our analysis. The vertical velocity at 850 mb level was obtained from National Centers for Environmental Prediction (NCEP) reanalysis data, regridded to 1° to 1° resolution and separated based on MODIS retrieved AOD as "clean", "moderately polluted" and "heavily polluted". If the subsidence is solely responsible for the observed variation in morning-to-afternoon differences in cloud properties for different AOD cases, one expects to see the comparable variation in the magnitude of omega and the morning-to-afternoon changes in cloud properties. Figure 4 shows 7-year averaged omega fields (Pa/s) at 1800 UTC (1200 - 1300 LT) and MODIS observed morning-to-afternoon differences in CF and COT plots segregated by the aerosol loading. While location and seasonality of the subsidence (regions with positive omegas) are in a general agreement with the detailed modeling studies (e.g., Garreaud and Muñoz, 2004), Fig. 4 does not indicate the robust relationship between the subsidence and the morning-to-afternoon variation in cloud properties for different aerosol loadings (see also Auxiliary material Fig. S5). Considerable distinction in large-scale subsidence for different aerosol loadings was also not established for 12 and 18 UTC differences in omega fields (not shown). While it is practically impossible to fully separate aerosols from meteorology, and it has been established that climatic factors are controlling location and diurnal cycle of marine stratocumulus, our results indicate that increased aerosol concentration may lead to enhanced reduction of afternoon cloud coverage and optical thickness. This result is consistent with the recent modeling studies suggesting potential reduction of aerosol indirect forcing in polluted stratocumulus clouds (Ackerman et al., 2004; Lu and Seinfeld, 2005; Sandu et al., 2008; 2009). Recent LES studies (Sandu et al., 2009) further show, that for the same dynamical forcing variables, diurnal amplitude in liquid water path for polluted marine stratocumulus clouds could be more than 40

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2. Further, recent results from the VOCALS Regional Experiment have not found heavy loadings of black carbon in most samples taken, be they in aircraft or on the ground. It would be difficult to believe that the semi-direct effect is a strong player in this region.

The aerosol induced suppression of precipitation and subsequent enhancement of entrainment drying was proposed as the potential mechanism leading to the daytime reduction of cloud water (Ackerman et al., 2004; Lu and Seinfeld, 2005; Sandu et al., 2008; 2009). The text has been modified to clear-up the confusion.

References:

Ackerman, A. S., Kirkpatrick, M. P., Stevens, D. E., and Toon. O. B.: The impact of humidity above stratiform clouds on indirect aerosol climate forcing. Nature, 432, 10148211;1017, 2004.

Bretherton, C. S., Uttal, T., Fairall, C. W., Yuter, S. E., Weller, R. A., Baumgardner, D., Comstock, K., and Wood, R.: The EPIC 2001 stratocumulus study. Bull. Amer. Meteor. Soc., 85, 967 - 977, 2004.

Garreaud, R. D., and Muñoz, R.: The diurnal cycle in circulation and cloudiness over the subtropical southeast Pacific: A modeling study. J. Climate, 17, 1699 - 1710, 2004.

Lu, M.-L., and Seinfeld, J. H.: Study of the aerosol indirect effect by large-eddy simulation of marine stratocumulus. J. Atmos. Sci., 62, 3909 - 3932, 2005.

Sandu, I., Brenguier, J. L., Geoffroy, O., Thouron, O., and Masson, V.: Aerosol impacts on the diurnal cycle of marine stratocumulus, J. Atmos. Sci., 65, 2705 - 2718, 2008.

Sandu, I., Brenguier J.-L., Thouron O., and Stevens B.: How important is the vertical structure for the representation of aerosol impacts on the diurnal cycle of marine stratocumulus? ACPD, 9, 5465 - 5503, 2009.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 1489, 2009.