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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Understanding the drivers of marine liquid-water cloud occurrence and properties with global observations using neural networks" *by* Hendrik Andersen et al.

Anonymous Referee #2

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This paper addresses a topic of significant current research, namely quantifying the effect of aerosols on cloud properties. The authors note the importance of local meteorology in determining the properties of clouds and that as meteorological factors are also correlated to aerosol properties, this can obscure the influence of aerosols on cloud properties. To explore the role of meteorology and aerosols, they make use of an artificial neural network (ANN) to examine the sensitivity of cloud properties to different predictors. Similar to previous studies, they show that meteorology is a strong control on the cloud properties, such that the cloud properties can be accurately predicted on a monthly timescale using reanalysis data and observed aerosol properties.

I think that this paper is a good addition to the literature on this topic, presenting a

new way to investigate the drivers of cloud properties. However, there are a couple of points, listed below, that I think should be clarified before publication. I particular, I think that using monthly data rather than daily/instantaneous data must be better justified. It would also make the paper stronger if the ANN method was compared to a more comparable statistical technique, such as a multiple linear regression across meteorological parameters. This might help to highlight the benefits of using an ANN, especially if it results in a different sensitivity of cloud properties to aerosol. Following these changes, I feel that this article would be suitable for publication in Atmospheric Chemistry and Physics.

Main points

While some previous studies have used monthly data for investigations into aerosol-cloud interactions, this disguises a lot of the variability in the cloud field and focuses on very large scale changes in cloud properties. The effect of seasonal variations can generate non-causal relationships between cloud properties and meteorological factors that might be accounted for if the study was done on a sub-seasonal scale using higher temporal resolution data. Can the authors explain why monthly data is used in this case and why daily data is unsuitable?

The use of an ANN seems to give a large improvement over just using AOD as a predictive variable for cloud properties. However, I am not sure this is a suitable comparison, as AOD is rarely assumed to be a good predictive variable for cloud properties on its own. As better comparison would be the predictive ability of (log) AOD on its own using a linear regression and from the ANN. Alternatively a comparison of a multiple linear regression and an ANN for predicting the cloud properties could show the added utility of using an ANN over existing methods. This might then highlight further useful properties of the ANN - for example, does it show a stronger (or weaker) sensitivity of cloud properties to aerosols when compared to current methods?

How do regional ANNs compare to a single global model? Presumably if enough mete-

orological parameters can be included, a single global model should be able to predict cloud properties everywhere. Requiring different models in different locations would then indicate that some meteorological parameter is missing from the ANN. A global pattern of the accuracy of the ANN might then give an indicator as to which parameters should be included. The ANN might be expected to differ as a function of cloud type, but perhaps a separate model for each cloud type (e.g. Gryspeerdt and Stier, 2012 or Oreopoulos et al., 2016) might be useful.

Minor points

P2L9: Perhaps only e.g. is necessary

P2L24: Why is the 2.1um effective radius used with the 3.7um LWP retrieval?

P2L29: Is the liquid fraction a suitable measure of cloud fraction, as it depends on the overlying ice cloud fraction? The authors could consider using cases where only liquid cloud exists in a gridbox, as this would remove this source of uncertainty.

P3L4: AOD is proportional to CCN (at least at some scales, see Andreae, 2009), it is just not a direct measurement (the same as with mass, as it also depends on aerosol optical properties)

P3L7: Many recent studies have used aerosol index (AOD times angstrom exponent) or a reanalysis aerosol parameter (e.g. Lebsock et al., 2008; McCoy et al., 2016). As these have been shown to more accurately predict cloud properties, they might further improve the skill of the ANN. Although MODIS AI is not necessarily accurate over land (Levy et al., 2013), it could be used over ocean in this study.

P3L13: It is definitely a good idea to investigate variables that have been previously used in aerosol-cloud studies. Koren et al., (2010) might also provide some useful guidance here. Although it was focussed on looking at convective clouds, some of the results (e.g. Figs. 8,9) might help decide which variables should be included in the ANN).

P4L33: Is there any significance behind using five hidden nodes?

P5L7: Are the sensitivities calculated using the local variation of meteorological values, or the same artificial values globally? If the relationship is non-linear and the mean values of the meteorological variables vary across the globe, this could strongly affect the calculated sensitivity.

P5L14: I am not sure I understand this sentence (which might explain my previous query?)

P5L20: If the other meteorological factors in the ANN are held constant, does this produce a different result for the simple sensitivity? (see main point)

P6L7: As I understand it previous work focusses on the sensitivity as this is related to the strength of the cloud response to aerosol. It is not often assumed that aerosols can explain much of the variability in cloud properties which might explain the low skill here.

P7L1: Perhaps another measure of skill might be useful in addition to the Rˆ2? It could be argued that the skill in the shallow cumulus regions is quite good, in that the ANN (presumably) gets the cloud properties roughly right (the rms error might be small)?

P7L4: Does this removal of the poor skill models bias the results, perhaps as a function of meteorology (as would appear to be the case from the maps in Fig. 3)

P7L9: How does these sensitivities compare to previous results? Several studies have calculated AOD-CF or AOD-droplet number concentration sensitivities which could be compared here (e.g. Quaas et al (2008), Grandey et al. (2012), Gryspeerdt et al. (2016))

P12L3: Are the covariations really spurious? The argument here is not that the covariations don't exist, but that they are not representative of the causal relationship. I would suggest that if 'direct physical relationship' was replaced with 'causal relationship', this could instead mention the issue of confounding variables, similar to Gryspeerdt et al.,

(2016).

P12L4: To what extent has using RH in the ANN accounted for this effect?

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