Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2017-154-RC1, 2017

Atmospheric Measurement Techniques Discussions

Interactive comment on "Retrieval of optical thickness and droplet effective radius of inhomogeneous clouds using deep learning" *by* Rintaro Okamura et al.

Anonymous Referee #1

Received and published: 27 July 2017

This article presents the possibility to use of deep neural network (DNN) to retrieve cloud properties (optical thickness and effective radius) accounting for the horizontal photon transport. This is so far not accounted for in the classical algorithm, that use the homogeneous cloud assumption. This is a move in the way to improve remote sensing algorithm and account for 3D radiative effects. However, the presentation and explanations do not put the paper in favor. Consequently, several precisions and corrections need to be added in the paper before publications. They are indicated below.

Major comments:

1) The originality of the paper seems to be more related to the possibility to make a multi-pixel inversion of cloud properties than to use DNN. It should appear in the title. I suggest "Feasibility study of multi-pixels retrieval of cloud optical thickness and effective radius using deep neural network"

2) Abstract is too succinct and need to be completed.

3) In the introduction, the authors described similar works, they did previously to retrieve COT and CEDR accounting for neighboring pixels (Iwabuchi et Hayasaka, 2003). Through the paper, the disadvantages of this previous method comparing to the new one are not sufficiently explained. I did not understand "which was an obstacle to generalizing the algorithm (p2, li10)". Which obstacles? Does it not the same problem with the NN method ? The authors should add a discussion about the advantages/disadvantages and about the implementation of each method in the introduction or in the conclusion A comparison of previous method and DNN method in terms of results will also be valuable.

4) li 15-22: Some important references are incorrectly cited: Faure et al. (2001) is about the retrieval of mean cloud properties accounting for the sub-pixel heterogeneities while Faure et al. (2002) concerns the retrieval of cloud parameters from high-resolution data using adjacent pixels which is a different study. This second one is the closest to the current study. Correct it also in section 4.2. These two papers are major because they are the first papers in the fields but they are limited to fluxes and not applicable to real data. Following the paper of Faure et al., 2001, which is for medium spatial resolution, Cornet et al. (2004) present ways to apply to real data heterogeneous cloud retrieval using NN. It is finally tested on real data in Cornet et al. (2005) on MODIS data. The paragraph citing these studies about cloud neural network retrieval needs to be clarified.

5) To my knowledge, this is the first time in atmospheric science that Deep Neural Network (DNNs) are used. More explanations are needed in a specific section explaining

clearly how it works and allowing to understand some affirmations and vocabulary used in the text. For example, in the introduction, why “a DNN is more suitable for approximating complex non linear functions” than a classical NN? What is “automatic feature extraction”, can the authors give an example? For the same reasons, Section 3.1 are confuse and consequently not very clear for a non-expert in deep learning. It needs to be separate with generality on the DNN in the specific section rewritten with more explanation and in a pedagogical way. Some schemas may also help to understand. Another section should specify to the choices made (see major comment 6 below). In the specific section about DNN should appears what is “shortcuts DNN”(p5, li 17) or what is convolutional layer ? How the filter weights are obtained? Can the authors also explain in few lines the paper of He et al. (2015) in order that the readers understand?

6) p5 . There is also no enough explanation about the choice of the input vector and the architecture of the DNN. Li- 5-10: why these two input vectors? The paragraph should start with an explanation of the philosophy. The first input vector is built in order to correct IPA retrieval and the second to retrieve directly cloud properties. I’m wondering also why four wavelengths and not only two as for the bi-spectral method? Does the authors test this last configuration with two wavelengths? I’m wondering also how the architecture of the DNN was chosen (convolutional layer or not, activation function or not), does the authors made test to find the best architecture?

7) P7- li 28-30: I am not completely agree with the assertion “the DNN retrieves COT values that are close to the true values assumed in the test, successfully corrected the phase lag.” In Figure 6-a, near 11.7km, DNN-2r retrieval shows also large differences and near 17km clearly the DNN retrievals overestimate the COT and the phase lag is not completely cancelled. Can the authors be more precise in the description of the figures? In addition to cross-sections, could also the authors add the relative errors transects and the RMSE of the different retrievals to have more qualitative idea of the improvements. Same remarks concerning Re retrieval.

8) p8, li 1-6: Concerning Re retrieval with the homogenous cloud assumption, it is not

really surprising to obtain large differences between homogeneous assumption and true results. The overestimation with IPA is not only related with shadowing effects. Indeed, homogeneous cloud assumption involve homogeneous Re profile. From satellite remote sensing, the upper part of the cloud is retrieved (See for example Platnick et al. 2000). Therefore, if the effective radius is vertically increasing in the cloud, the retrieved Re is larger than the mean Re. For the DNN, training with heterogeneous clouds allows to learn the relation between vertically averaged Re and radiances. Discussion about this issue (p8, li 20-24) is too late in the paper and should be moved here. Try also to highlight better the shadowing by reporting for example the difference between true COT and homogeneous COT as in Cornet et al. (2015) or Marshak et al., (2006).

9) P9, section 4.2: Authors made comparisons with previous works of Faure et al., 2002 but the settings are exactly the same. First, only pairs of wavelengths were used and not the four wavelengths mentioned. In addition, in the study of Faure et al., (2002), 15 neighboring pixels of each side of the target pixels were used (62 components in the input vector) and here only 3. This can change a lot the results. The comparisons have to be done again with the same parameters than the one used in Faure et al. (2002) or at least the same conditions that the DNN, that is 10 pixels for each side, otherwise, it is not possible to conclude the comparisons and to know really why retrieval is better (DNN or neighboring pixels?)

Minor comments:

1) p. 1, li 17: why the bispectral method follows the IPA assumption? The authors should add reasons why in the text (time computation, simplicity, others?) and also insist about the independence of each cloudy columns which is considered infinite.

2) p.2, li 5: Until which distance, have the neighboring pixels to be considered ? can the authors here or further in the text give some values and references ?

3) p3, section 2.1: what are the resolution and dimension of the generated cloud fields?

4) p3, li 17: IPA (Independent Pixel Approximation) does not mean that the vertical profiles is homogeneous but only that each pixel is considered independently of his neighbors. Authors should speak about the homogeneous cloud assumption horizontally as well as vertically

5) p3, eq. 3: Why the authors used the square of the usual definition of the inhomogeneity parameter defined in the others study. For comparisons, it seems to be better to use the same definition.

6) P5, li 9: Radiances at 3.75micron is used, I suppose that is only the solar part. It should be precise in the text that thermal correction need to be done before using this wavelength.

7) p5: explain why the number of pixels considered in the input vector (10x10) is larger than those considered in the output vector (8x8 or 6x6) and why it is not the same for the two DNN. 8) P6, li10: add the URL for the chainer framework

9) P6, eq 8 and9: is there a justification for the choice of these functions?

10) P7, li 14: DNN and IPA are not really comparable: the first is an inversion tools as look-up tables and the second one is a direct model. It seems better to write multipixels-DNN inversion versus IPA-LUT inversion.

11) Figure 5 and 6: Precise data corresponds to only the test data set or to a mix between the training and test dataset

12) p7, li 22 and Figure 5 and 6: precise the geometry of the observation: view zenithal and azimuthal angles?

13) p7: li 26: illumination and shadowed effects are well-known under IPA assumption: please add some references

14) p7: li 26: Large errors are due to the flattening of the relation-ship between radiances and COT due to saturation effects: a small difference in radiance lead to a quite

large difference in COT.

15) p8, li 9, figure 7 : I agree that the bias (mean error) is particularly large only for COT less than 1. For COT > 1, the difference in errors is not so important. For COT >10, the standard deviation is larger for IPA meaning that dispersion (roughening) is more important.

16) Figure 8: Could the authors indicate the COT and Re associated with the filters and be more precise in the description of the figure? Which filters patterns are “symmetrical around the center” and how is distributed the optical thickness? Also on which figures does appear “the feature related to the solar direct beam”? Comments also the difference between wavelengths.

17) Section 4.2: are the same training set and generalization set used for all the NN trainings?

18) p9, li 30-33: add the issue concerning the vertical profiles for Re in the conclusion.

19) P10: in the conclusion, can the authors insist on the limitations of using NN methods such as the one related to database used and extrapolation issues. In other words, how will work the DNN is the cloud is quite different to those used for the training dataset?

20) P10: Following the previous points, can the authors speaks about the steps needed in order to develop an operational multi-pixels algorithm?

References: Cornet, C., Buriez, J-C., Riédi, J., Isaka, H. and B. Guillemet, 2005: Case study of inhomogeneous cloud parameter retrieval from MODIS data, Geophys. Res. Lett, 32, L13807, doi:10.1029/2005GL022791.

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