

Interactive comment on “Adaptive neuro fuzzy inference system for profiling of the atmosphere” by K. Ramesh et al.

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Reply to Interactive comment on “Adaptive neuro fuzzy inference system for profiling of the atmosphere” by K. Ramesh et al. by Anonymous Referee #3 Received and published: 16 July 2014

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Note: As suggested by honorable anonymous referee 3, we have separated non rainy days microwave radiometer brightness temperatures and trained ANFIS again to see the impact of clouds on training of ANFIS system. In revised manuscript we have referred as ANFIS(NRD) i.e. ANFIS trained using microwave brightness temperature inputs only on non-rainy days observed during June-September 2011. The ANFIS

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presented in earlier manuscript is referred in revised manuscript as ANFIS(RD+NRD) i.e. ANFIS trained using microwave brightness temperature inputs on rainy and non-rainy days observed during June-September 2011. The all figures are plotted again and shown in revised manuscript. We have modified the revised manuscript section according by taking views and suggestions of both honorable referees.

1. Comment: In this paper, temperature and humidity profiles are retrieved from ground based microwave radiometer (MWR) using Adaptive neuro fuzzy inference system (ANFIS) for the region centered around NARL, Gadanki, India. The method has been compared against the artificial neural network retrieval algorithm which has been in use for temperature and humidity profile retrieval from MWR. The retrieval approach using ANFIS is shown to be superior over ANN. The attempt of using ANFIS for retrieval is appreciated and this work also has the potential for publication; however, the authors have to make significant changes to make this paper scientifically appealing. The paper needs to be organized and structured properly and following are some of the major revisions.

Answer: Authors are thankful to honorable anonymous referee for critically reviewing paper and appreciating the efforts. The manuscript is revised according to the valuable comments of honorable referee and answers are mentioned below.

2. Comment: In general, this paper has to be substantially revised. Many sentences are vague and seem to convey the wrong information. This paper lacks a through literature survey and many facts have been quoted without giving a proper citation. The introduction in this paper is a mix of methodology, results and some general facts, at the same time lacking citations for the previous works which have employed ANFIS for retrieval. This is odd as far as scientific paper writing is concerned. Methodology and results need to be presented under their respective sections and not in the introductory part. Simply doing a google search will help the authors to find papers which can be mentioned in the introduction.

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Answer: The paper is substantially revised by taking comments of both referees into consideration. The literature survey added to the introduction of the paper. The care has been taken to add proper citation where facts are stated. The discussion related to methodology is removed from the introduction and mentioned in the section 3 of this paper. The introduction and references cited in this paper are provided as supplementary material.

3. Comment: Another weakness which I found is the way the ANFIS method has been introduced. Please note that the ANFIS method is just for fine tuning the fuzzy rules and it works similar to ANN. I believe that the retrieval accuracy using Fuzzy logic based retrieval approach is not so different from that of ANFIS. The important part here is the formation of fuzzy rules, relating the MWR brightness temperature to atmospheric temperature and humidity values for each layer in the atmosphere. More effort should be put in to explain this part clearly and concisely. This paper fails to provide adequate information in this regard Answer: The detailed description of the ANFIS method is introduced in the section 3 of revised manuscript. The detailed structure of ANFIS also depicted in Fig. 2 in revised manuscript. The separate section added to describe fuzzy logic (Takagi and Sugeno) and its usage in ANFIS then the description of Sugeno type subtractive clustering (Chiu 1997, Yager and Filev 1994) used for incorporating knowledge from input (microwave brightness temperatures) and output (radiosonde profiles) is made. The efforts are made to address the concern raised by honorable referee 3 with more systematically and clearly.

Takagi, T. and Sugeno, M.: Derivation of fuzzy control rules from human operator's control action, in proc. IFAC Symp. Fuzzy inform., Knowledge Representation and Decision Analysis, pp. 55-60, July 1983. J.-S. R. Jang, C. T. Sun, and E. Mizutani, Neuro-Fuzzy and Soft Computing. Upper Saddle River, NJ: Prentice-Hall, 1997, ser. MATLAB Curriculum Series. Stephen L. Chiu, Fuzzy Information Engineering: A Guided Tour of Applications, ed. D. Dubois, H. Prade, and R. Yager, John Wiley & Sons, 1997. Yager, R. and D. Filev, "Generation of Fuzzy Rules by Mountain Clustering," Journal of

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Intelligent & Fuzzy Systems, Vol. 2, No. 3, pp. 209-219, 1994.

4. Comment: Authors should also mention the source of the algorithm used in this paper. A good explanation of the algorithm and proper citations of similar previous works will improve the paper and also help the readers to understand and use the method.

Answer: The detailed description of the ANFIS method is introduced in the section 3 of revised manuscript. The detailed structure of ANFIS also depicted in Fig. 2 with citation of previous work.

5. Comment: Though it is demonstrated that ANFIS retrieval perform better than ANN, I am afraid that the statistics are not robust enough to convey a meaningful conclusion. I say this mainly because of the low number of data points used in training and validation. I don't think MWR can give useful information under rainy conditions. I strongly suggest a redoing of the retrieval calculations including more number of datasets for the training and validation phases to provide an unbiased estimate of retrieval accuracy. This should be performed for rainy and non-rainy conditions separately. Also, the explanation on setting up of ANFIS algorithm for retrieval is very vague. The authors may improvise on the following, Answer: As suggested by honorable referee 3, we have redone the retrieval calculations by adding more number of datasets. The two ANFISs are developed separately for non rainy days and rainy + non rainy days. The scatter plots and bias are calculated and shown in Fig. 3 a and b. The discussion on retrieval accuracy of both ANFISs is included in section 4. The elaborate discussion on ANFIS retrieval algorithm is made in section 3.

6. Comment: The title Since the work is intended for temperature and humidity profile retrieval and not for profiling the atmosphere, the title should reflect this. Answer: Title is modified according to the suggestion of honorable referee. New title of the revised manuscript is "Adaptive Neuro Fuzzy Inference System for Temperature and Humidity Profile retrieval from Microwave Radiometer Observations"

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7. Comment: Abstract Line 10: What is meant by modelling the profiles of atmospheric parameters? Aren't the MWR measurements used to retrieve the temperature and humidity profiles? Line 10: In this work ANFIS is not used as a forecast model rather it is used for retrieval. Please change. Answer: The word 'model' is changed to 'retrieve' in this line. The sentence is modified as below. "The observations of brightness temperatures recorded by Radiometrics Multichannel Microwave Radiometer MP3000 for the period of June – Sept 2011 are used to retrieve the profile of temperature and relative humidity up to 10 km."

8. Comment: Line 20: The error analysis of profiles concludes that the retrieved profiles using ANFIS technique have improved the retrievals substantially; however, retrieval of RH by both techniques (ANN and ANFIS) has limited success > First of all, you are not doing any error analysis on profiles rather it is done on the retrieved profiles. Secondly, it is not clear as to where the ANFIS retrieval has improved? Do you mean temperature retrieval?

Answer: The sentence is modified as below: "The analysis of retrieved profiles concludes that ANFIS techniques have improved the retrievals of temperature profile substantially; however, retrieval of RH by both techniques (ANN and ANFIS) has limited success."

9. Comment: Introduction Page 2718, Line 15: Many nonlinear statistical/evolutionary algorithms are being developed to retrieve the profiles of the atmosphere using MWR. Artificial neural networks (ANNs) are one of them, which are widely used for different types of infrared and microwave sounding instruments > Please provide references. The following sentence should also be provided with reference

Answer: The sentence is modified as a paragraph mentioned below (Please refer to supplementary material submitted along with these reply).

Recent developments in the retrieval algorithms and computational techniques are adaptive and devise a model (Gaffard Tim Hewison, 2003) which improves the perfor-

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mance and accuracy of radiometer retrievals. Many nonlinear statistical / evolutionary algorithms are being developed for retrieving the profiles of atmosphere using MWR (Solheim, 1998). These includes ANN, Newtonian iteration of statistically retrieved profiles, Bayesian most probable retrieval, etc. Artificial Neural Networks (ANNs) is widely used for different types of infrared and microwave sounding instruments (Frate and Schiavon, 1998; Binco et. al., 2005). Frate and Schiavon, 1998 presented an inversion technique to retrieve profiles of temperature and water vapor using MWR. Their techniques combined a profile over a complete set of orthogonal function with ANN which performs the estimate of coefficient of the expansion itself. Their analysis shows that this technique is flexible and robust. Kottayil et al 2010 used a new nonlinear technique ANFIS to improve the first guess using simulated infrared brightness temperature for GOES-12 sounder channels. They found results of ANFIS retrieval are robust and reduces root mean squared error by 20% compared to regression fitting. They also argued that as ANFIS use Fuzzy Information System (FIS) for the classification of input, the classification of training dataset is not needed as it is required for regression techniques.

10. Comment: Page 2718, Line 15: The observed profiles of equivalent potential temperatures indicate preconditioning of the vertical column of the atmosphere to be conducive to the occurrence of thunderstorms about 3–4 h prior to their actual occurrence (Fig. 1a) > This is actually a result, so please remove this part to the introductory part of the result section. Also, please mention the source of the profile of potential temperature Answer: Removed from the introduction of the paper and mentioned in the result section appropriately. Also the formula for calculating equivalent potential temperature included in section 3.

11. Comment: Page 2718, Line 20: The ANN used in this MWR is useful to train vertical profiles observed at sites using radiosonde observations, microwave radiances and vertical distribution of weighting functions > What is conveyed here? Is it that ANN is trained with an ensemble of profiles and the corresponding MWR brightness

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temperatures? What is the role of weighting function here please? Do elaborate

Answer: No, ensemble profiles are not used for training ANN. The weighting function here we mean that the microwave weighting function generally used by radiative transfer models to retrieve height information. The ANN uses simple back propagation neural network developed by Stuttgart University. As this sentence confusing the reader we have rephrased this statement in revised manuscript as suggested by honorable referee 3.

12. Comment: Page 2719: ANFIS is a nonlinear computational intelligent system that adapts itself by forming rules to survive with changing environment and uncertainty > Please note that ANFIS does not form any rules. Basically, it strengthens the relationship between input and output devised through the fuzzy logic approach. Move the following sentences on fuzzy logic and ANFIS to appropriate section in the Methodology part. Instead, a through literature survey on previous studies done with ANFIS can be provided here. Answer: The sentence modified in revised manuscript. The elaborated description of FIS and ANFIS is incorporated with suitable references as mentioned above.

13. Comment: Page 2719: ANFIS tunes a Sugeno-type interface system and generates a single output of a weighted linear combination of the consequents (Jang et al., 2007). Therefore, such methods are useful for retrieving atmospheric profiles based on the passive microwave remote-sensed brightness temperatures at different frequencies observed by MWR > The ANFIS method hasn't even been introduced here and prematurely saying that it generates single output of a weighted linear combination of the consequents will only confuse the reader. This needs to be removed from this part Answer: As suggested by honorable referee the section 3 reorganized and rewritten by taking these suggestions into consideration in revised manuscript.

14. Comment: Page 2720: These channels are selected based on their sensitivity to the occurrence of thunderstorms over the study site > Under rainy conditions, MWR

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measurements are not very useful. Then how relevant is the channel sensitivity here? Answer: The microwave radiometer available at NARL operates at 31 frequencies at Ka and V bands. However the training of ANFISs using all microwave brightness temperatures at all frequencies was difficult job. Therefore, we have studied the time series of variation of brightness temperatures observed by microwave radiometer on the days of thunderstorms. We found 10 channels selected in this study shows increase in magnitude of 3 - 4 hours prior to occurrence of thunderstorms. This aspect discussed in revised manuscript in detail and we have included plots of variation of brightness temperatures on thunderstorm day of May 28, 2013 for clear description of selection of input to ANFISs.

15. Comment: Page 2720: From available observations, 80% of observations are used for training of ANFIS and 20% of observations are used for the validation of the ANFIS model > Please clarify as to how many data points you have in total and out of this, how many are used for training and validation? Page 2720: same period of the training data set '???' Lacks clarity and seems vague. Also applicable for all places this appears. Answer: The datasets used for training and testing the ANFIS retrievals are described in detailed in revised manuscript. The period of the observations used for training and validation ANFIS model is from June to September 2011. The ANFIS model validated for 30 days viz. June 24-30, July 21-31, August 26-31 and September 26-30, 2011. The brightness temperature data observed from MWR for all the days of monsoon months (June-September) of the year 2011 at 12:00 UTC each day, excluding dates selected for validation are used as an input to ANFIS system in training phase. As regular profiles of radiosonde are available at each 12 UTC, the ANFIS system trained for 12 UTC observations. ANFIS system would have been more robust if it would have been trained using many radiosonde observations at regular interval each day. Unfortunately the obtaining periodic profiles of radiosonde at regular interval for long duration (monsoon months) to train ANFIS system are not economically feasible.

16. Comment: Page 2721: I have a general suggestion about the structure of the

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methodology part. The authors could introduce the fuzzy logic part first, providing the details of fuzzy logic and the nature of fuzzy rules used in the present algorithm. Then could move to detailing the clustering algorithm applied to the dataset. This can be followed briefly by the ANFIS part, the ANFIS model structure. The authors may cite the reference of Jang paper here. But do provide the details of how the inputs and output are handled in the network since the ANFIS network changes premise (input) and consequent (output) parameters during the training phase, which is worth mentioning. Right now, under section ANFIS, the description on fuzzy logic and ANFIS are mixed up. In this section, some works related to ANFIS are cited which are best placed if moved to the introduction section. Answer: As suggested by honorable referee the section 1 and section 3 are reorganized and rewritten by taking these suggestions into consideration in revised manuscript.

17. Comment: Page 2721, Line 15: The fuzzy logic is used for classification of the input data set in different classes and forms the input to an artificial neural network. Then ANN is used to predict the output based on the training data sets. Thus fuzzy logic controls the way of processing data by its classification to minimize the error in the neural network prediction (Tahmaseb and Hezarkhani, 2010) > Fuzzy logic is not used for the classification of input data, but is used for formulating a relationship between input and output through IF –THEN statements and it does not minimize any error. I think the authors have some real confusion about how the whole formulation works. Please consider rewriting. Answer: The sentence is rewritten as per suggestions of honorable referee.

18. Comment: Page 2721, Line 20: To avoid this, subtractive fuzzy clustering has been used to build the fuzzy rules. This helped in reducing the number of rules, automatically determining the number of clusters by assuming each data point as a potential cluster center and creates clusters based on the density > As I have mentioned earlier, the details on the clustering part should come under fuzzy logic formalism and the explanation could be more elaborative. Answer: The elaborated description of FIS and

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ANFIS is incorporated with suitable references as mentioned above.

19. Comment: Page 2722 ANFIS model structure: Again note that the authors have mentioned about the fuzzy logic and data clustering here which should be removed. See my comments above about the suggested structure of the methodology. Answer: The elaborated description of FIS and ANFIS is incorporated with suitable references as mentioned above.

20. Comment: Page 2723: When acronyms are used for the first time in the main text, they should be expanded. Answer: MAE, RMSE and SMPE acronyms expanded in the revised manuscript.

21. Comment: Page 2725: You may remove Figure 3 from the paper showing the retrieval performance of the algorithm during the training phase; this doesn't convey any information about the actual retrieval accuracy of the present algorithm. It is not surprising that the network provides the best fit for the training dataset. You may mention this in the text if you like. Answer: As suggested by honorary referee the Figure 3 removed from the paper. The relevance discussed in the text of revised manuscript.

22. Comment: Page 2725, Line 10: Please note that the RMSE of RH should be in % RH and not in degree Celsius. This is attributed to a relatively higher frequency of observations available over these heights that enabled better learning of the ANFIS algorithm. Why are the numbers of observations different for different heights? Answer: The sentence corrected in revised manuscript. The discussion on available datasets and testing dataset is discussed in detail in revised manuscript.

23. Comment: Page 2725, Line 20: Figure 4 is not at all clear. How many observations are there for days which are shown in the x-axis and also for what height is this shown? Note that the MWR channel sensitivity lies within 0-4 km of the troposphere and the degradation of the retrieval accuracy at higher altitudes especially for RH profiles results from lack of information content from these heights. Authors may mention this in the text. Answer: As suggested by honorable referee it is mentioned in the manuscript.

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24. Comment: The figures 5(d) and 6 (d) show that the biases in temperature and humidity retrieval using ANFIS is not systematic and it is of random nature; at the same time, the ANN retrieval seems to have systematic biases. The reason for this behavior should be mentioned. It would also be appropriate to do a scatter plot between retrieved and observed value which will give an idea about the regions where retrieval performance is good / bad. Answer: We have calculated the bias for both parameters (temperature and RH) for all levels (as suggested by honorable referee 1 in comment no. 6 as well as honorable referee 3 comment number 24) and shown in new figures 3 (a and b). It is seen from the figures that there is significant reduction in bias for ANFIS (RD+NRD) retrieval algorithm compared to ANN and ANFIS(NRD) retrieval algorithm. However, it is seen from the analysis that ANN has more systematic bias compared to both of other algorithms. The paragraph on this aspect is added to section 4: results and discussions.

25. Comment: Another aspect worth looking into is the impact of clouds on observed MWR brightness temperature and consequently its retrieval. Since the MWR channels are sensitive to temperature and humidity fluctuations with in the boundary layer, the presence of liquid clouds do affect the brightness temperature observed in MWR water vapour channels centered around 22 GHz. During June to September, low level clouds (liquid clouds) are persistent over the Indian land region. Therefore, the authors could also think about the impact of liquid clouds on humidity retrieval below 4 km altitude Answer: The authors are thankful to honorable anonymous referee for valuable and constructive suggestion. Based on the suggestion to estimate we have done literature survey and found recent important works such as Lifegren et al, GRL, 2012 (DOI: 10.1029/2000JD900817); Guzman et al, AMT, 2014. However, we feel that more systematic study is required to retrieve cloud liquid water and identifying its effect in contaminating of retrieved RH profiles. We strongly feel it can form basis of another paper. In this paper we have added a paragraph discussing about this in the conclusion section.

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26. Comment: Finally, it is also recommended that the authors go for thorough grammatical corrections. Answer: The grammatical corrections are applied to the manuscript.

Please also note the supplement to this comment:

<http://www.atmos-meas-tech-discuss.net/7/C2205/2014/amtd-7-C2205-2014-supplement.pdf>

Interactive comment on Atmos. Meas. Tech. Discuss., 7, 2715, 2014.

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