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Interactive comment on "Comparing the cloud vertical structure derived from several methods based on measured atmospheric profiles and active surface measurements" by M. Costa-Surós et al.

Anonymous Referee #2 (Received and published: 23 August 2013)

Review of the article titled "Comparing cloud vertical structure derived from several methods based on the measured atmospheric profiles and active remote sensors" by Costa-Surós and coauthors for publication in the Atmospheric Chemistry Physics. The authors have used data from the ARM SGP site in Oklahoma to deduce cloud vertical structure using the balloon borne radiosondes and active remote sensors like cloud radar and lidar. They have also used data from the GOES to characterize the cloud structure. The study compares different techniques proposed in the past literature to deduce cloud layers from the radiosonde data among each other and to that observed by the ground based active remote sensors and satellite data. They also propose modification to one of the technique so as to be comparable to the Global Climate Model (GCM) resolution. Although the idea of comparing the different techniques and observations for detecting cloud layers is innovative, the article fails to do detailed analysis of the reasons of the poor performance of the techniques or observations.

Hence I recommend this article for publication with major revisions.

We thank Referee 2 for his/her positive appreciation of this work. The performance of the tested techniques (methods) may seem somewhat poor, but given the complexity of the system we reported a relatively high percentage of perfect agreements. We know that there are still "false negative" and "false positive" cases. However, at least some of them come from the fact that ideal conditions for comparing measurement with estimations do not exist. Note that ideal conditions would be:

- RS totally vertical.
- RH and T measurements without any error (see answer in the second specific comment of reviewer 1).
- Completely stationary meteorological situation.

It is obvious that none of these conditions can ever be accomplished: during the ascent, RS always suffer some horizontal displacement; all measurements bring some uncertainty; and the atmosphere is continuously changing.

This discussion will be added in the paper if finally accepted for publication.

Major Comments:

1) Radiosondes are launched at the ARM SGP site four times a day. Out of the data from the entire year (1460 sondes), you've only used 125 soundings. This is a major drawback of the study. I highly recommend the authors to use as many soundings as possible in their study. This will make the statistics robust, as currently you have low number of samples. Also, the way cases have been selected is a little confusing; it almost seems that there is no objective way the soundings have been selected.

We appreciate this criticism, and we have added more study cases to our work. However, the number of cases is limited by the effort we perform to 1) select those situations that are suitable for the comparison analysis (recall that this means visual scrutiny of GOES images) and 2) obtain cloud layers from the ARSCL product and compare them with the RS methods (which require as well a notable manual intervention). In addition, we think that results are robust enough because general conclusions have not changed when using around 200 cases (in the new version of the study, see Tables below) instead of using 125 cases. Moreover, we have computed a confidence interval for the perfect agreement, which will be added to the final version of the paper (see Reviewer #1, specific comment #5).

Moreover, in our answer to your comment #8 we will provide more detail about case selection.

This table will substitute Table 4 of the paper (Behavior of the six RS methods for cloud detection compared to ARSCL observations):

ARSCL (Visu)			Situation		METHOD					
Situation	Num. Cases	%			PWR95	WR95	CE96	DS99	MNS05	ZHA10
No clouds	94	48.7	**No clouds**		**73**	**67**	**49**	**69**	**93**	**72**
			Clouds (1st CBH)	Low	12	10	18	10	1	6
				Middle	9	12	7	13	0	6
				High	0	5	22	2	0	10
1 layer	58	30.1	No clouds		1	1	5	1	20	4
			1 layer	**Coincident**	**21**	**16**	**1**	**11**	**27**	**29**
				Not coincident	2	0	8	1	1	2
			>1 layer	*Some is coincident*	*33*	*40*	*17*	*45*	*9*	*23*
				Any coincidence	1	1	25	0	1	0
2 layers	32	16.6	No clouds		1	1	2	0	11	1
			1 layer	*One is coincident*	*5*	*8*	*1*	*4*	*12*	*10*
				No coincidence	0	0	1	0	2	0
			2 layers	**Coincident**	**3**	**5**	**0**	**5**	**4**	**3**
				One is coincident	*6*	*1*	*2*	*1*	*2*	*5*
				Any coincidence	0	0	1	1	0	1
			>2 layers	*One is coincident*	*7*	*4*	*14*	*7*	*1*	*7*
				2 coincident	*10*	*13*	*7*	*14*	*0*	*5*
				Any coincidence	0	0	4	0	0	0
> 2 layers	9	4.7	No clouds		1	0	2	0	4	2
			Perfect agreement		**0**	**0**	**0**	**0**	**0**	**0**
			Approximate agreement		*8*	*9*	*6*	*8*	*5*	*7*
			Any coincidence		0	0	1	1	0	0
			False negative		1,6%	1,0%	4,7%	0,5%	18,1%	3,6%
			False positive		10,9%	14,0%	24,4%	13,0%	0,5%	11,4%
			Not coincident		1,6%	0,5%	20,7%	1,6%	2,1%	1,6%
			Approximate agreement		*35,8%*	*38,9%*	*24,4%*	*40,9%*	*15,0%*	*29,5%*
			Perfect agreement*		**50,3 ± 7.1 %**	**45,6 ± 7.0 %**	**25,9 ± 6.2%**	**44,0 ± 7.0%**	**64,2 ± 6.8%**	**53,9 ± 7.0%**

*CI: confidence interval of Perfect agreement at 95% of confidence

This table will substitute Table 6 of the paper (Behavior of the tests performed on ZHA10 method compared to ARSCL observations):

ARSCL (Visu)					METHOD					
Situation	Num. Cases	%	Situation		ZHA10	ZHA10i	ZHA10i-a	ZHA10i-b	ZHA10iLR	ZHA10 LRnew
No clouds	94	48.7	**No clouds**		**72**	**77**	**90**	**79**	92	90
			Clouds (1st CBH)	Low	6	4	2	4	1	2
				Middle	6	6	2	3	0	0
				High	10	7	0	8	1	2
1 layer	58	30.1	No clouds		4	5	16	6	12	7
			1 layer	**Coincident**	***29***	***35***	***31***	***33***	**34**	**36**
				Not coincident	2	0	1	1	3	0
			>1 layer	*Some is coincident*	*23*	*18*	*10*	*17*	*9*	*15*
				Any coincidence	0	0	0	1	0	0
2 layers	32	16.6	No clouds		*1*	*1*	*5*	*1*	2	2
			1 layer	*One is coincident*	*10*	*12*	*14*	*13*	*18*	*17*
				No coincidence	0	0	4	0	0	0
			2 layers	*Coincident*	*3*	*4*	*2*	*3*	*2*	*3*
				One is coincident	*5*	*5*	*1*	*5*	*5*	*4*
				Any coincidence	1	2	0	2	0	1
			>2 layers	*One is coincident*	*7*	*3*	*3*	*3*	*3*	*3*
				2 coincident	*5*	*5*	*3*	*5*	*2*	*2*
				Any coincidence	0	0	0	0	0	0
> 2 layers	9	4.7	No clouds		2	1	3	1	1	1
			Perfect agreement		**0**	**0**	**0**	**0**	**0**	**0**
			Approximate agreement		*7*	*8*	*6*	*8*	*8*	*8*
			Any coincidence		0	0	0	0	0	0
			False negative		3,6%	3,6%	12,4%	4,1%	7,8%	5,2%
			False positive		11,4%	8,8%	2,1%	7,8%	1,0%	2,1%
			Not coincident		1,6%	1,0%	2,6%	2,1%	1,6%	0,5%
			Approximate agreement		*29,5%*	*26,4%*	*19,2%*	*26,4%*	*23,3%*	*25,4%*
			Perfect agreement*		**53,9 ± 7.0%**	**60,1 ± 6.9%**	**63,7 ± 6.8%**	**59,6 ± 6.9%**	**66,3 ± 6.7%**	**66,8 ± 6.6%**

*CI: confidence interval of Perfect agreement at 95% of confidence

2) Page 14420 line 1-5: you've plotted the sounding on the ARSCL recorded cloud boundaries. The plots are shown in Fig 2-5. Although this is a good approach to start, it is not scientific. I recommend you plot the relative humidity on the upper x-axis by converting the distance to time using the wind speeds at various heights. This will be a significant improvement to the paper. This will also address the cloud in-homogeneity issue.

We are not sure if we understand this comment. The aim of figures 2 to 5 was to show the evolution of clouds as detected by ARSCL through time (i.e., visualize if cloud layers were constant or not during and around the RS ascent), showing at the same time the vertical position of the RS. Then, we looked at the lat/long coordinates of the sonde when it reached that height, and then looked at the nearest (in time) satellite images to guess whether that location had clouds. This procedure allows us to guess if the sonde may have crossed a cloud layer.

We say guess because just because there is cloud evident at that lat/long in the satellite image is no proof that there was cloud at that height in the location the sonde is at. Especially if there were higher clouds around, because one can only see the highest cloud in the satellite image and have no idea whether there is cloud below or not. But the opposite is definitely true. If there are no clouds evident in the satellite at the lat/long of the sonde, then we know that there is not a cloud at any height there, so this is not a suitable case for this work. In other words using the satellite data has eliminated cases when there just weren't clouds at the ARSCL detected height where the sonde ended up at that height. But there might still be some error the other way, there may be cloud where the sonde is but no guarantee it is at the same height as the ARSCL cloud.

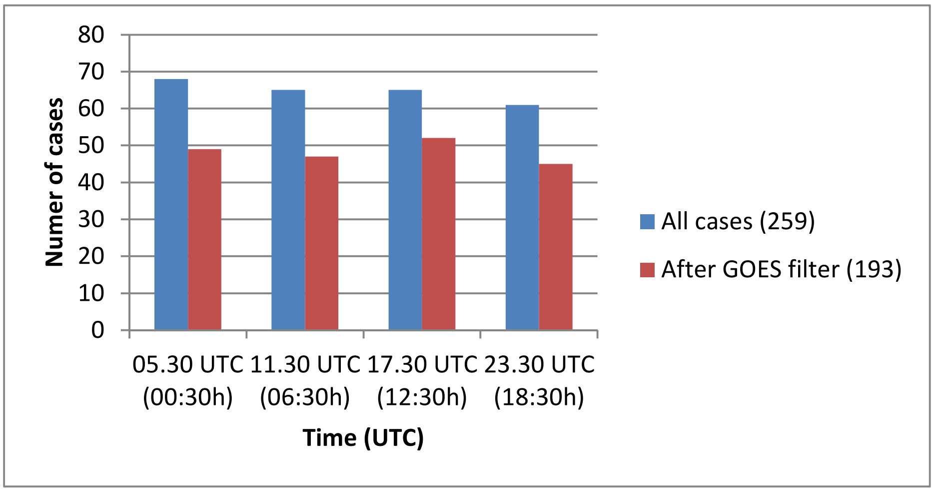
In relation to this comment, and answering the first addition question/hint from reviewer #1, an example of an RH profile will be included as a new Figure 1..

3) Panels in Fig 6 should be added to the respective case they are referring to. It is ok, to only show one snapshot of the Total Sky Imager. So you can have four panels for all the figures from 2-5. Another idea, since this is an online publication, would be to completely remove the TSI images from figures 2-5 and then make animated GIF loops of the TSI images for each day out of the example cases. The single TSI images next to the current figures do not add much to the paper.

Again, we appreciate this suggestion, so we will added every satellite image to every case study in figures 2 to 5, so figure 6 will be deleted. In addition, TSI images will be deleted from Fig. 2, 4 and 5 and will be provided as additional material, in form of 3 animated TSI images showing the time evolution of clouds.

4) In the second of the four example cases, you used a radiosonde launch from nighttime, when no visible satellite data or TSI image is available. The lack of this data is detrimental to your study because part of your method involves checking for cloud homogeneity of the surrounding area and that cannot be applied for this case. A much better example case for low clouds would be a case during the daytime hours, much like the other three example cases.

We have included a nocturnal example deliberately because we note such cases are also included in the whole database used in our analysis. We strongly think that night cases must be included in the study for comprehensiveness. In fact, day and night cases are equally represented in the database. At night satellite visible images are not available but the infrared images give us the necessary information about the homogeneity of the cloud field.



5) While you argue that you have been able to visibly check for cloud homogeneity in the surrounding area by looking at both the visible and infrared imaged from the GOES satellite (in order to compare ARSCL data and radiosonde data), I am not quite convinced that this method is scientifically solid, especially since the median displacement distance of the radiosonde from the launch site is very large (79 km!!). How have you taken into account secondary (and tertiary, etc) cloud layers that exist below the uppermost layer?

We have used GOES images to confirm that cloudiness conditions of the study cases are homogeneous enough across the radiosounding trajectory and to exclude from the analyses those study cases which are not. Of course this procedure is limited by the top-down view of satellite images. Therefore, it is true that we cannot assure 100% that among the endorsed cases there is not any inhomogeneity, especially in lower clouds. But our screening does address the opposite: we eliminate cases with obvious inhomogeneity or when there are no clouds present at the sonde location when it reaches the ARSCL cloud height.

Since our study is about cloud vertical structure, several cloud layers, if present, have been taken into account. However, we cannot guarantee the homogeneity of layers below the uppermost layer from the satellite view, so some inhomogeneous cases are probably included in the database. This may be the reason for part of the disagreements between the sonde methods and ARSCL.

The complexity of the situations included in the analysis is in part addressed and discussed in the "Case studies" section.

6) Page 14410, line 20: Please explain why there is a need to lower the resolution of the technique designed to retrieve the cloud vertical structure from the radiosonde data. The temperature and moisture profiles simulated by GCM and the cloud layer profile from the GCM are related to each other in a much more complex way than any of the listed retrieval technique. The cloud vertical structure retrieved from the GCM simulated temperature and moisture profiles, is not comparable to the GCM simulated cloud structure as the simulated cloud structure depends on the parameterization used which are fairly complex.

Strictly speaking, there is not a need, but we think that this test gives more interest to the study and makes it more complete. We do not pretend to substitute any existent methodology or parameterization in GCM or NWP models. We intended to say that these methods could be used, for example, to test model outputs such as reanalysis products. These products are known to produce questionable cloudiness, since their primary purpose is the accurate representation of the dynamics and cloudiness is secondary, yet the cloudiness data are sometimes used as reference. The results of lowering the vertical resolution show that the method from this study can use the reanalysis temperature and humidity profiles to see if clouds are produced as well to compare with the reanalysis data.

We think that testing that method performance does not depend on profile resolution should be addressed in our study to give more confidence to our results. In fact, we demonstrate that a lower resolution profile does not worsen the method performance. Moreover, high (vertical) resolution data are not available at many of the sonde launching sites around the world. Thus for those sites we only have the lower resolution GTS messages. So it is good to show that the method works for lower resolution, thus one could use the GTS resolution to some good effect.

7) I believe that your equation for Total Agreement (where Total Agreement = Perfect Agreement + Approximate Agreement) is flawed. Approximate agreement should not be given the same weight as Perfect Agreement since a case can have approximate agreement even though the majority of the cloud vertical structure was wrongly identified, so long as one layer was correctly identified. To make your results more robust, it would be helpful to create a weighted equation for Total Agreement, so that Perfect Agreement carries more weight than Approximate Agreement. In doing this, your results should change, and it should become more apparent which method is correct MOST of the time (and which method correctly identifies the most cloud layers), rather than which methods identify at least one cloud layer correctly.

The reviewer is right and in fact, the other reviewer raised a similar question. We understand the concern and we deleted the "total agreement" from tables 4 and 6 and from the discussion because it may confuse the reader. In the final version of the paper, we will present the results without joining the "perfect" and the "approximate" agreements (see Tables above, Major comment #1), and we will give more importance to the "perfect agreements".

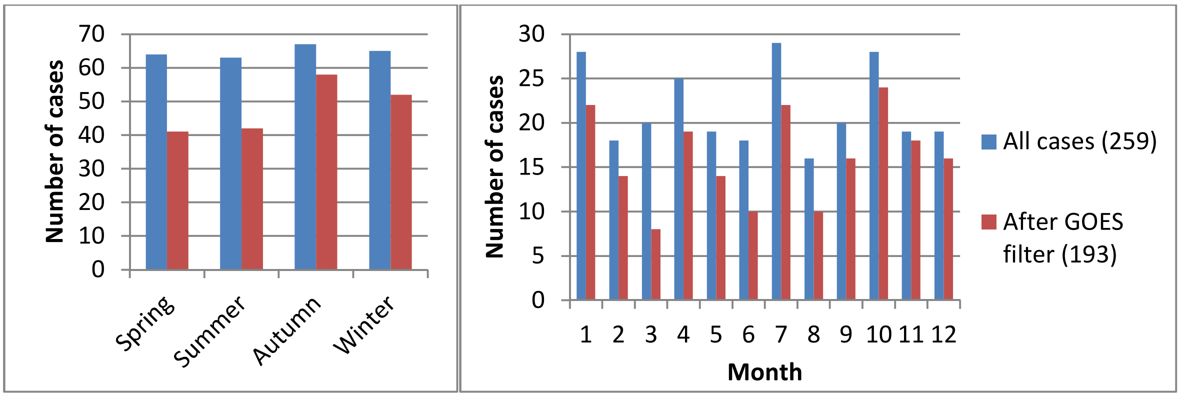
This question is also commented in the answers to Referee #1 (Specific comment #4)

An additional idea would be break down Approximate Agreement into different categories (where each category has its own weight in the equation of Total Agreement), where one category could be a method that correctly identifies at least 25% of the cloud layers, another category could be a method that correctly identifies 50% of the cloud layers, and another category could be a method that correctly identifies 75% of the cloud layers.

Although we appreciate the reviewer suggestions, any combination of perfect and approximate agreement results would be arbitrary, so we decided to remove the total agreement from the results, discussion and tables.

8) It would be helpful if an additional figure were added to the paper that showed a time distribution of the radiosonde data that was used. So please plot the time in months on the x-axis and the number of radiosondes used from that months on the y-axis for the year 2009.

As explained in our answer to comment 1, we have added more study cases to the analysis. The new cases have been chosen having in mind an equilibrated seasonal distribution along the year. Specifically, we have selected approximately one out of every five days (a total of 65 days) totaling 259 available radiosoundings. After applying the GOES images based filtering, a total of 193 cases remain for the comparison study between RS methods and ARSCL. The monthly and seasonal distributions of these cases are shown below. We will explain the case selection in the final version of the paper, but we think that the figures are not necessary.



9) The article contains several grammatical mistakes. Also the writing style can be improved to help the general flow of the article. I highly recommend the authors to give the article a thorough read to correct the grammatical mistakes and improve the writing. Several of the grammatical mistakes are pointed out as minor comments below. Thanks.

We want to thank the reviewer for the detailed revision.

Minor Comments:

1) Reference to Mather and Voyles (2012 BAMS) should be added as it has thorough description of the instrumentation at the ARM sites.

We will include this reference in the introduction (in fact is *Mather and Voyles,* 2013)

[Mather, J. and J. Voyles (2013), THE ARM CLIMATE RESEARCH FACILITY A Review of Structure and Capabilities*, Bull. Am. Meteorol. Soc., 94*(3), 377-392, doi: 10.1175/BAMS-D-11-00218.1]

2) The classification used for low, middle and high clouds seems arbitrary; please follow the convention used by ISCCP. http://isccp.giss.nasa.gov/cloudtypes.html

We want to thank the referee suggestion but the thresholds “0-2000-6000 m” have been taken from the WMO classification which is an international reference and is not so different from your proposal. We will include in page 14420-14421 the WMO reference (*World Meteorological Organization,* 1975).

[World Meteorological Organization (1975), International Cloud Atlas. Manual on the observation of clouds and other meteors*, WMO, I*]

3) Table 5 lists the seasonal value of agreement between different techniques in percent. Similar to Table 4, please also mention the number of sondes. Also, please mention the months rather than the seasons.

The number of cases will be included in table 5. However we will maintain the seasonal (and not monthly) basis, as it is quite common in meteorological/climatic studies.

4) Page 14409, line 1 and also elsewhere: The word is ceilometer and not ceilometerS.

Thanks.

5) Page 14407, line 1-5: The high level cirrus cloud warm the surface because they are transparent to the shortwave radiation but opaque to the longwave radiation.

It will be added to the manuscript.

6) Page 14407, line 8-11: Your sentence beginning with "Moreover, Crewell et al. (2004)…" is worded in a very confusing way. Please change the sentence

7) Page 14409,line 15-16: Your sentence beginning with "Some of them add conditions…" is poorly written.

8) Page 14409, line 27: "They concluded that theWang and Rossow (1995) method…"

9) Page 14410, line 4: It is Wang instead of Wand.

10) Page 14410, line 5: "every radiosonde instrument…" NOT instruments

11) Page 14410, line 9: "radiosonde" NOT radiosondeS

12) Page 14411, line 16-18: In your sentence beginning: "The greatest strength…", add the word 'it' "…but it may miss some…"

13) Page 14411, line 18-20: Your sentence beginning, "Yet the detection…" is a fragment.

13) Page 14412, line 13: "ascend" not ascent

14) Page 14412, line 18-20: Your sentence beginning, "The used profiles…" should be edited as follows: "…as a result of taking measurements every 2 s and having an ascent rate in the range of…"

15) Page 14413, line 8-9: "Considering these…crossed by the RS…"

16) Page 14415, line 21-22: Your sentence beginning "The WR95 method…" should read: "..by comparing cloud properties…"

17) Page 14415, line 23-24: Your sentence beginning, "The Radiosonde data…" is not properly formatted and does not make sense.

18) Page 14416, line 26-28: Your sentence beginning, "For this reason,…", should read: "…resolution to approximately the same..."

19) Page 14420, line 12-13: Your sentence beginning, "Then, the next step..." should read: "...of the six methods described above...".

20) Page 14421, line 12: The sentence should read: "Thus, Figs 2 to 5 are composed of...".

21) Page 14421, line 24: The sentence should read: "...every 3 km in height...".

22) Page 14423, line 27: The sentence should read: "According to the results...".

23) Page 14424, line 16: The sentence should read: "...than actually in existence...".

24) Page 14425, line 14: Please add a comma in this sentence (after 'method'): "...approximately double that for any other method, indicating that this...".

25) Page 14425, line 21: The sentence should read: "...across the year."

26) Page 14429, line 6-7: The sentence should read: "...in order to assure the homogeneity of the cloud field in the region, so that a suitable comparison can be made, GOES images..."

We want to thank the referee for all this typos that will be corrected in the revised manuscript.