

## ***Interactive comment on “Collocating satellite-based radar and radiometer measurements – methodology and usage examples” by G. Holl et al.***

**Anonymous Referee #1**

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### **General comments**

The authors describe a simple collocation procedure between radar and radiometer (satellite) sensors on different or the same platform. In particular, they focus on the NOAA-18 Microwave Humidity Sounder MHS and the CloudSat Cloud Profiling Radar CPR and produce a publicly available data set of collocations for 2007. These collocations are used in three different ways to show their usefulness: 1) to validate the operational NESDIS MHS Ice Water Path (IWP) product against CloudSat CPR 2) to validate radiative transfer simulations of AMSU-B/MHS brightness temperatures; and 3) to feed an artificial neural network that derives IWP from MHS (and HIRS) measure-

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ments using CPR as a reference.

The paper is well structured, contains much information about the instruments and methodologies applied and addresses an important topic that fits to AMT. Therefore, it should be published after minor revisions.

### **Specific comments**

The main “deficiencies” of the paper are 1) the description of the collocation procedure that must be partly rephrased (Section 3.1.1) and clarified before publication, and 2) the conclusions.

As far as the collocation procedure is concerned, it would be useful to have a short overview stating that the collocation procedure consists of three steps: in the first one orbit sections are selected according to a “rough” temporal criterion; in the second and most interesting step the spatial criterion is implemented; and in the third step the temporal criterion is applied to single measurements. Furthermore, the second step should be clarified according to the following remarks and open questions:

**Page 829, line 4:** “1. The maximum speed...” This sentence means that first the distance in km between successive points is computed for both ground tracks *A* and *B* and then the maximum distance is assumed to be the maximum speed of the ground tracks. Is it correct? Please clarify this in the text.

**Page 829, line 6:** I suggest to separate item 2. “Start with  $n = 1$ , find close points...” in two separate items:

2. “Start with  $n = 1$ .”
3. “Find close points...”

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- (a) “Choose  $N$  samples spread over  $B$  dividing  $B$  in  $N + 1$  intervals”: Is track  $B$  divided in  $N + 1$  *equal* intervals, i.e. all containing the same amount of points? If not, how do you select the single intervals? After interval definition  $N$  samples are extracted: does it mean that you extract  $N$  *points* out of these  $N + 1$  intervals? How are they distributed over the  $N + 1$  intervals? Or do you mean that these  $N$  sample points divide the track  $B$  in  $N + 1$  intervals such that they represent the edges of the intervals (excluding the first and last point of the ground track)?  
“Profiling with different values has shown that  $N = 200$  works well.”: Could you please explain how  $N$  depends on MSH’s and CPR’s footprint size and which further factors affect in principle the determination of  $N$ ?
- (b) “Find which sample is closest to  $A_n$ .” Does sample again stand for point?
- (c) “Consider the interval between the neighbouring samples.”: Does this mean that starting from the sample point on  $B$  determined in (b) you now consider its neighbouring sample points (two at most) and the (at most two) intervals that have as edge points on one side the sample point found in (b) and on the other side one of the neighbouring points? Please clarify.  
“If the spatial condition is met for the edges of any interval (e.g. neighbouring sample), include the next interval as well, until either the spatial condition is no longer met or the start or end of the ground track is reached.”: Now you check whether the spatial condition is fulfilled by the samples. Of course, you have to start with the point determined in (b) and then you switch over to the neighbouring points mentioned above and check them as well. Is this correct? When do you include an interval? When both edges meet the spatial condition? If yes, aren’t you missing points in intervals that are only partly contained in a MHS footprint? Please clarify.

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- (d) “Calculate the distance for all points in this interval.”: Why do you talk about one interval? In principle, you could have selected more than one interval in (c). By “distance” you mean the distances between  $A_n$  and all points contained in the intervals selected in (c), don’t you? Please clarify.  
The use of such a spatial criterion means that you consider the MHS footprint as circular while you show in Fig. 1 that they are elliptical. Is this a restriction to your collocation procedure? In principle, you could proceed in two ways: 1) you are restrictive and consider only those CPR measurements that “really” belong to a MHS footprint, but this is probably not what one always needs, or 2) you first collect all CPR data points that could belong to a MHS footprint and then select only those that really belong to it in a second step (at this point you could also take care of the spatial response function of the MHS). Please comment on this already at this point in the text or more clearly at the beginning of the section (page 828 line >21) and not only further down on page 830 lines 5–19.

**Page 829, line 19:** Please replace “repeat” with “start again from 3.”, i.e. from “Find close points...”.

**Page 829, line 20–24:** Please add “and start again from 3.” at the end of line 22. Why is it guaranteed that you are not missing any collocation when you make the jump proposed here? Please clarify.

I think that a figure would be very helpful to better understand how the collocation procedure works.

**Page 830, line 5:** Here probably the set of points determined through the procedure on page 829 is used as a basis for the check of the temporal condition. Please clarify.

As far as the conclusions (**Page 844**) are concerned, please modify the manuscript according to:

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The Conclusions are too short and not informative enough. Please add a sketch of the collocation procedure which is the main topic of the paper. The three applications can also be described in some more detail and results, validation and discussion should be put right after the application description. For instance, the ANN is mentioned first on page 844 line 17 and then again on page 845 line 7.

Can you discuss the applicability of the method to other instruments other than radar and radiometer? Does the method work also when pixel sizes of the instruments to collocate are of the same order? What are the restrictions and drawbacks of the presented method? What are again the main differences (advantages, disadvantages) w.r.t. Nagle and Holz (2009)?

**Page 844 line 26:** Please replace “One can also improve the collocations...” by “One can extract additional information from other high-resolution data to better characterise the collocations...”.

Further comments regarding the full manuscript:

**Page 823, line 16:** Please state briefly why ice clouds are important for climate.

**Page 826, line 6:** Please explain why you neglect differences between AMSU-B and MHS, and whether they are large or not in terms of radiances.

**Page 827, line 4:** Please illustrate HIRS’s spatial resolution and footprint.

**Page 827, line 8:** Not always the spatial extent of clouds is of the order of 10–20 km, so I would say that the spatial extent of a measurement is of the same order or one order of magnitude larger than the spatial extent of a cloud. Please specify in the text.

**Page 827, line 17–24:** Please mention the role of the spatial response function for the two datasets, in particular for the second one where averages are taken. In general,

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the notion of “response function” should be replaced in the entire paper by “spatial response function” or “point spread function”. Every radiometer also has a spectral response function so this is a source of possible confusion.

**Page 828, line 4–5:** “... the position of the satellite is not available and not required for the procedure”: You should add here “in contrast to Nagle and Holz (2009)”, otherwise it is not clear why you mention this at this point.

**Page 828, line 15–17:** By “... our maximum time interval is 15 min, we consider the data in the interval 10:45–11:45, or 10:45–11:30 in the CPR granule and 11:00–11:45 in the POES granule.” you mean here “... our maximum time difference is 15 min, we consider the data in the interval 10:45–11:45, or more precisely 10:45–11:30 in the CPR granule and 11:00–11:45 in the POES granule.”. Please specify.

**Page 828, line 21:** At page 828 lines 15–17 you talk about the first temporal criterion that is applied to the data. Here you start the paragraph with “First, ...” but actually you should say something like “Starting from the orbit data screened according to the first temporal criterion as explained above, ...”. Please correct.

**Page 830, line 5:** Please mention explicitly that you consider at this point only those measurements that meet the spatial criterion exposed at page 829.

**Page 830, line 21–23:** Do you mean the average, the standard deviation and the coefficient of variation of the measurements or of the IWP product? Please clarify.

**Page 830, line 22:** The use of a fixed distance threshold of 7.5 km ensures that CPR pixels are contained in MHS pixels, however this could also reduce their representativeness of the MHS pixel. Please add a short comment on this.

**Page 831, line 20–21:** Sometimes it is useful to only consider simultaneous nadir observations, so maybe Nagle and Holz (2009) had a particular application in mind. Can you please comment on this?

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**Page 832, line 3–5:** Please rephrase and specify the last part of this sentence "...where the distance was permitted to be up to 15 km": "...where the maximum distance between MHS and CPR centre points did not exceed 15 km and the time difference between MHS and CPR measurements was limited to ???".

**Page 832, line 13:** CloudSat is the first satellite of the A-Train after Aqua.

**Page 833, line 15–18:** Please rephrase the first part of this paragraph. In particular, the first sentence is not clear and it is not clear what "population" in the second sentence means.

**Page 834, line 1–2:** Please explain why no MHS pixel contains 14 or 15 CPR pixels as anticipated at the beginning of Sect. 3.3.

**Page 834, line 5:** Please replace "through the centre" with "close to the centre".

**Page 834, line 7:** Please specify: which coefficient of variation is plotted here? Of CPR IWP inside the MHS pixels? Please maybe also remind the reader of the definition of coefficient of variation here or before in the paper.

**Page 834, line 13–16:** Please replace the concept of a "strong cloud" with a more physical one (thick cloud?).

**Page 834, line 28:** Please draw some conclusion about the criteria that one can use to minimise sampling effects.

**Page 835, line 21:** Please replace "treshold" by "detection limit".

**Page 836, line 6:** Please explain the meaning of "simulated radar observations for aircraft ice particle data". What is " aircraft ice particle data"?

**Page 836, line 15–17:** Please explain the aim of this comparison: what do you intend to show? Why is it important for this paper?

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**Page 836, line 19:** Which measurements do you use then? How many simulations do you perform? Please add this information to the text.

**Page 837, line 4:** Please comment in the text about the accuracy and the reasons for assuming spherical ice crystals.

**Page 837, line 17:** You mentioned on page 826 that you neglect differences between AMSU-B and MHS, but does AMSU-B channel 20 correspond to MHS channel 5?

**Page 837, line 23–25:** Is this a good approximation? Please comment on this.

**Page 838, line 1:** Do you weight IWP? Nature and clouds do not know anything about antenna patterns.

**Page 838, line 19–20:** What is the reason for this isolated sentence? Do these differences contribute to the differences mentioned above? How?

**Page 840, line 29:** Please explain what is meant with "columns 45 and 46 in the MHS data".

**Page 841, line 16–17:** How can you say that (a) and (d) do not contribute to the variability observed? Do you refer to results presented in the next lines/pages or are there other reasons for this assertion?

**Page 841, line 28:** What is meant by "the MHS measurements for all collocations"? Do you mean all MHS considered or only the subset of MHS measurements where collocations could be found? Please clarify.

**Page 842, line 11:** Which steps in  $\sigma$  do you take?

**Page 843 line 8–9:** Do you use collocated HIRS, MHS and CPR measurements to feed a new ANN and then test this new version of the ANN against CPR? Does the number of collocations remain the same because HIRS is carried by NOAA-18 together with

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MHS? Please add some detail about this.

**Page 843 line 8–9:** Why don't you use brightness temperature differences between HIRS channel 8 and HIRS channel 10 (12.47  $\mu\text{m}$ )? This difference is very sensitive to thin cirrus.

**Page 843 line 9–10:** Actually, one has already here the impression that low IWP values can be better retrieved now.

**Page 843 line 11:** Why are there no values for very small IWP when the MHS-HIRS-CPR neural network is used? They were present before the addition of HIRS.

#### Technical corrections

Please use either "onboard" or "on-board" or "aboard" consistently through all the paper.

Please replace the notion of "response function" in the entire paper by "spatial response function" or "point spread function" (see above).

**Title:** "examples of use" instead of "usage examples"?

**Page 822 line 5:** "onboard the CloudSat CPR" → "onboard CloudSat".

**Page 823 line 10:** "The collocations considered here are between" → "The collocations considered here are mainly between": you also mention other satellites.

**Page 823 line 15:** "for the climate" → "for climate".

**Page 823 line 16:** " the different General" → "different General".

**Page 824 line 13:** "as CloudSat and passive" → "as CPR on CloudSat and passive".

**Page 824 line 18:** "the CloudSat" → "CloudSat CPR".

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**Page 824 line 25:** "between CloudSat" → "between CloudSat CPR".

**Page 825 line 5:** "onboard the CloudSat" → "aboard CloudSat".

**Page 825 line 18:** "A-train" → "A-Train".

**Page 825 line 23–24:** "we assume CloudSat to be true" → "we assume CloudSat CPR to represent the truth since it is supposed to provide the most accurate measurements of IWP".

**Page 825 line 24–25:** delete "and are stored in 25 High-Definition Format (HDF)" since this does not matter to the paper.

**Page 826 line 11:** "It scans" → "It scans across-track"?

**Page 826 line 19:** AAPP = ??

**Page 826 line 27:** "because clouds are clearly visible" → "because ice clouds are clearly visible": lower (warm and thus water) clouds are not visible in a water vapour (humidity) channel.

**Page 827 line 4:** "A scan" → "A HIRS scan".

**Page 827 line 21–22:** Please specify that average IWP and standard deviation refer to average IWP derived from CPR and to the standard deviation of IWP derived from CPR.

**Page 828 line 18–19:** "In our approach, we use a two-step approach" → "We use a two-step approach".

**Page 828 line 22:** "true size" → "true pixel size".

**Page 828 line 25:** Add "or a weighting of them to consider the MHS spatial response function".

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**Page 830 line 6:** Replace “CloudSat” with “CPR”.

**Page 830 line 8:** Replace “CloudSat” with “CPR”.

**Page 830 line 12–15:** Rephrase: “For each collocation and for each sensor (CPR, MHS, HIRS and AMSU-A), we store the location (lat/lon), the measurement time, the time of the first measurement in the file (to help finding the file containing the measurement) and the location of the point inside the datafile (row/column).”

**Page 830 line 16–17:** “time interval” → “time difference”.

**Page 830 line 23:** “are contained by the MHS pixel independent of the scan” → “are contained in the MHS pixel independently of the scan”.

**Page 830 line 25:** “ $1 \text{ g m}^{-2}$ ” → “ $1 \text{ g m}^{-2}$  of ice”.

**Page 831 line 7:** “They search the rows”: which rows? Please explain.

**Page 832 line 16:** “time interval” → “time difference”.

**Page 832 line 18:** “subsattelite” → “subsattellite”.

**Page 832 line 19:** “roughly” → “roughly”.

**Page 834 line 17 and following:** Please replace “bars” with “dots”.

**Page 835 line 25:** “fregencies” → “frequencies”.

**Page 836 line 2:** Add a reference to Sect. 3.3 at the end of the sentence.

**Page 838 line 22:** “brightness temperature” → “brightness temperatures”.

**Page 840 line 1:** “is averaged over” → “comprises”.

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**Page 840 line 4:** “In both cases, the observed radiance” → “In both cases, the observed MHS radiance”.

**Page 842 line 7 and following:** Please use “ANN” instead of “network”.

**Page 843 line 18:** Add “as expected” at the end of the sentence.

**Page 844 line 9–10:** “This be partly attributed because” → “This may be partly attributed to the fact that”.

**Page 844 line 10:** “frecuencies” → “frequencies”.

**Figure 2:** “CloudSat” → “CPR”.

**Figure 3:** Could you please add some more information (i.e. tick marks) to the x-axis?

**Figure 4:** Add that data was aggregated in intervals of 1 hour. Furthermore, it is not possible to distinguish between small numbers of collocations and zero collocations. Could you please plot 0 collocations in black or white and leave the other colours to values  $> 0$ ?

**Figure 5:** “of the all” → “of all”.

**Figure 6:** This kind of plot is called a two-dimensional histogram. “CloudSat” → “CloudSat CPR”. “colour axis” → “colour scale”. “CS” → “CPR”.

**Figure 7:** “CloudSat” → “CloudSat CPR”. “log IWP” → “log IWP/ $1 \text{ g m}^{-2}$ ”. “The lines connecting from the boxes...”? “plotted as outliers”? Could you please explain the plot more clearly?

**Figure 8:** “correspond with” → “correspond to”.

**Figure 9:** “NN” → “ANN”. A little bit more text: “Scatter plot showing the performance of the ANN using MHS channels 3 to 5. The retrieved IWP is plotted against the input

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IWP”

**Figure 10:** “NN” → “ANN”. Please specify which ANN is used here.

**Figure 11:** See remark about Fig. 9.

**Figure 12:** “NN” → “ANN”. Error of? “with and without adding the HIRS channels” → “when only MHS channels are used or when both MHS and HIRS channels are used as input to the ANN.”

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