

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

G. Holl et al.

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1 General comments

Reviewer comment:

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) measurements 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.

Answer:

We thank the reviewer for the comments. In the supplement, we show the current manuscript along with a new figure and the differences with the manuscript as published in AMTD.

2 Specific comments**Reviewer comment:**

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.

Answer:[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)[Discussion Paper](#)



We address the deficiencies as described below.

Reviewer comment:

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:

Answer:

We have added the following at the top of page 828 (the beginning of section 3.1):

The collocation finding procedure consists of four steps. The steps are described in detail in the following text.

- 1. Orbits (granules) with time overlap are selected.**
- 2. Orbit sections are selected according to a rough temporal criterion.**
- 3. Measurements possibly fulfilling the spatial criterion are selected.**
- 4. The temporal criterion is applied to the selected measurements.**

Reviewer comment:

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.

Answer:

We have changed lines 4–5 on page 829 (the first element of the list) to:

The distance in km between successive points of the ground track is computed for both ground tracks, considering only the segments screened according to the temporal criterion discussed above. The maximum speed of the ground tracks is assumed to be the maximum distance.

Reviewer comment:

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...”*

Answer:

Full Screen / Esc

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Discussion Paper



We have implemented this suggestion.

Reviewer comment:

Page 829, line 6–14:

(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)?

Answer:

The intervals are of equal length, apart from the last interval, which is shorter. To clarify, we added the following text:

Choose N equidistant points (henceforth *samples*) from B as shown in Fig. 2 Combined with the first and the last point of the track, the samples define the edges for $N + 1$ intervals. All intervals contain the same number of points, with the exception of the last interval, that may contain less points than the others.

Reviewer comment:

“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 ?

Answer:

We have added the following text at the end of point 2 (now point 3):

As shown in Fig. 2, $N = 20$ is already sufficiently large to guarantee that any points in B meeting the spatial criterion are contained in the super-interval. However, with $N = 20$ the number of points in the super-interval for which the distance to A_n will be calculated is still quite large. A larger N means the super-interval will be smaller, but the number of samples for which the distance will be calculated will be larger. The choice of N is thus an optimisation problem to reduce the number of distance calculations. We have chosen $N = 200$.

Reviewer comment:

(b) “Find which sample is closest to A_n .” Does sample again stand for point?

Answer:

Yes, sample stands for point. We believe the text added at the beginning of (a) (see above) is now sufficiently clear.

Reviewer comment:

(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.

Answer:

We include an interval when at least one edge meets the spatial condition or if one edge is the sample closest to A_n . Thus, we are not missing any points. To clarify, we have added a figure and made two changes in the text:

- We have added to (b):

Call this sample B_m .

- We changed the text for (c) to:

Consider $B_{m+1}, B_{m+2}, \dots, B_{m+r}$ where B_{m+r} is the first sample that does not meet the spatial condition or the last measurement point of the granule. Consider $B_{m-1}, B_{m-2}, \dots, B_{m-l}$ where B_{m-l} is the first sample that does not meet the spatial condition or the first point of the granule. If N is large enough, all points that meet the spatial criterion are contained by the super-interval (B_{m-l}, B_{m+r}) , because the minimum of the distance from A_n to B will be contained by it (if N is too small, this interval may contain only a local minimum). An example of such a super-interval is shown by the thick line in Fig. 2. Consider this super-interval.

Reviewer comment:

(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.

Answer:

Here, we meant the interval consisting of several intervals. This was unclear. We have changed the terminology to “super-interval”. The text for (d) now reads:

Calculate the distance between A_n and every point in the super-interval.

Reviewer comment:

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.

Answer:

In the current manuscript, page 828 line 21–24 reads:

In the first step, we do not consider the true size or the sensor response function of either sensor. Instead, we treat the measurements as points and define a maximum distance to select the measurement pair for further consideration.

We believe this shows clearly enough that the approach is as in alternative 2) described by the reviewer.

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Full Screen / Esc

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Discussion Paper



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

Answer:

We have implemented this suggestion.

Reviewer comment:

Page 829, line 20–24: Please add “and start again from 3.” at the end of line 22.

Answer:

We have implemented this suggestion.

Reviewer comment:

Why is it guaranteed that you are not missing any collocation when you make the jump proposed here? Please clarify.

Answer:

To clarify and answer this question, we have changed the first paragraph of page 830 to:

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This works, because if the minimum distance from A_n to B is 120 km and the distance between A_n and A_{n+10} is 100 km, the maximum distance between A_{n+10} and B cannot be less than 20 km.

Reviewer comment:

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

Answer:

We have added a figure that shows how we select samples to divide the ground track in intervals, and how we select the super-interval to search for collocations.

We have thought about adding a figure showing that if the closest approach of B to A_n is 100 km, there is no chance that the closest approach of B to A_{n+1} can be less than 15 km if the distance between subsequent pixels in A is only a few kilometers, and that we can skip many points in A_n . However, we did not find a satisfactory way to illustrate this.

Reviewer comment:

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.

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Answer:

We changed the sentence starting at line 5 to:

From all points obtained with the procedure described above, those for which the time difference is less than 15 min are selected.

Reviewer comment:

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

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.

Answer:

We have added a figure illustrating a part of the collocation procedure. We did not find a good way to illustrate graphically the overall collocation procedure.

Reviewer comment:

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.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

We have rearranged the conclusions. We have changed the line previously at page 845, line 5 to:

One can make a stronger restriction for homogeneous scenes by looking at MODIS or AVHRR pixels inside the MHS, although this is limited as infrared measurements do not detect the vertical extent of the cloud. Another alternative is to combine MHS with other HIRS channels than those explored so far, or to directly input a combination of MHS and AVHRR for the training.

We added one line near the end of the article:

In particular, future work will focus on developing a global IWP product from passive microwave and infrared sensors available on operational polar orbiting satellites.

Reviewer comment:

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)?

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Full Screen / Esc

Printer-friendly Version

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Discussion Paper



We have added the following text:

In comparison with Nagle and Holz (2009), our algorithm is relatively simple. For example, it does not need satellite position data. It finds collocations even in the absence of simultaneous nadir observations.

Our method was designed for the case where one instrument is scanning and the other has a fixed viewing angle. It also works if both instruments are scanning, but in this case, it is slow and a different method is more suitable. If either satellite is geostationary or both instruments are on the same satellite, more optimised methods may be appropriate. The method does not depend on the nature of the sensor (active, passive) or the footprint size.

Reviewer comment:

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...”.

Answer:

We have implemented this suggestion.

Reviewer comment:

Full Screen / Esc

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Discussion Paper



[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)[Discussion Paper](#)

Further comments regarding the full manuscript: Page 823, line 16: Please state briefly why ice clouds are important for climate.

Answer:

We have changed this sentence to:

Ice clouds are important for the climate, because they absorb and scatter thermal radiation and reflect solar radiation, and thus influence the radiation budget of the Earth (Stephens, 2005).

Reviewer comment:

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.

Answer:

We have added the following text:

Although they are not the same, the standard deviation of the difference is much larger than the mean difference, so that a simple correction is not possible (Kleespies and Watts, 2007).

Reviewer comment:

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

Answer:

We have added a reference to Fig. 1, illustrating HIRS/4's spation resolution and footprint.

Reviewer comment:

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.

Answer:

We have added “or larger”. The line now reads:

The spatial extent of a measurement is of the same order as the physical extent of a cloud or larger (kilometers),

Reviewer comment:

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



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.

Answer:

We have added the following text:

For the averaging, we consider the CPR pixels as point measurements and the MHS pixels as circular measurements with a radius of 7.5 km and a constant sensor spatial response function inside this area. In reality, the sensor spatial response function of MHS is better approximated by a Gaussian shape.

Reviewer comment:

In general, 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.

Answer:

We have added “spatial” at each occurrence of “response function”:

- Page 828, line 22

- Page 828, line 24
- Page 830, line 18
- Page 831, line 9
- Page 831, line 15
- Page 831, line 17
- Page 837, line 25
- Page 844, line 23

Reviewer comment:

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.

Answer:

We have implemented this suggestion.

Reviewer comment:

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.

C477

[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)[Discussion Paper](#)

Answer:

We have implemented this suggestion.

Reviewer comment:

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.

Answer:

We have implemented this suggestion.

Reviewer comment:

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.

Answer:

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper





We have implemented this suggestion (see our answer to the reviewers more detailed suggestions on how to improve this section of the article).

Reviewer comment:

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.

Answer:

We have changed this line to:

For the second dataset, we collect the CPR pixels in an MHS pixel and calculate the number of CPR measurements, the average, the standard deviation and the coefficient of variation (standard deviation divided by mean) of the IWP product.

Reviewer comment:

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.

Answer:

We have added the following text:

Although this might reduce the representativeness, this effect is small compared to other error sources.

Reviewer comment:

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?

Answer:

We have added the following text:

For some applications, only simultaneous nadir observations are of interest; in this case, NH and our method should give the same result.

Reviewer comment:

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

C480

Full Screen / Esc

Printer-friendly Version

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Discussion Paper





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 ???”.

Answer:

We have changed this sentence to:

For the year 2007, we have found 124 822 977 collocations between the NOAA-18 MHS and the CloudSat CPR, 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 15 minutes.

Reviewer comment:

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

Answer:

We have changed the last part of this sentence to:

...and thus near CloudSat, because CloudSat is part of the A-Train.

Reviewer comment:

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.

Answer:

We have changed this paragraph to:

A collocation is considered representative, or good, if the CPR IWP statistics for the area covered by CPR are the same as the statistics of a hypothetical CPR IWP covering the full MHS pixel.

Reviewer comment:

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.

Answer:

This is because different criteria were used. We realise this text is confusing. We changed the sentence at line 11 to:

In the best case, a nadir MHS pixel contains around 15 CPR pixels (or only 13 when we limit the collocations to CPR pixels within 7.5 km of the MHS centrepoint).

Reviewer comment:

Page 834, line 5: Please replace “through the centre” with “close to the centre”.

Answer:

We have implemented this suggestion.

Reviewer comment:

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.

Answer:

We have changed this sentence to:

Figure 6b shows a histogram of the coefficient of variation of the CPR IWP product for the CPR pixels within 7.5 km of the MHS centrepoint.

Additionally, we have briefly defined the coefficient of variation at the first occurrence in the paper (page 830, line 21; see our response to the reviewer comment for **Page 830, line 21–23**).

C483

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Reviewer comment:

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

Answer:

We have implemented this suggestion (replaced “strong” by “thick”).

Reviewer comment:

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

Answer:

We have added the following text:

When the criteria discussed above are applied, sampling effects are reduced and a large number of collocations remain.

Reviewer comment:

Page 835, line 21: Please replace “treshold” by “detection limit”.

C484

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

We have implemented this suggestion.

Reviewer comment:

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

Answer:

We have changed the text to:

... simulated radar observations for ice particle data from aircraft in-situ measurements.

Reviewer comment:

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?

Answer:

It is relevant because it shows that the mapping obtained by the collocations can be used as independent information to verify statistics of a relation between radiances and IWP. We changed the text accordingly:

C485

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



The first dataset consists of the collocations, providing a mapping between brightness temperatures and independent IWP.

Reviewer comment:

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

Answer:

We have changed those two lines to:

The second dataset consists of a mapping generated from 30,000 synthetic atmospheres as described below. Note that this mapping predates the collocated measurements.

Reviewer comment:

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

Answer:

We have added the following text:

C486

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



We lack information about the true shape of the ice particles, which is different for different cloud types, and the most generic assumption is to assume spheres. This is also the assumption made by Austin et al. (2009) for the CloudSat CPR IWP retrieval. The accuracy of this approximation is difficult to assess, because the true microphysical parameters are unknown.

Reviewer comment:

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?

Answer:

Yes. We have added the following text:

...(corresponding to MHS channel 5)

Reviewer comment:

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

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Yes. We have added the following text:

For a diverse set of atmospheric profiles, the root mean square error between this approximation and a setup with a finer frequency grid is 0.020 K.

Reviewer comment:

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

Answer:

Yes. We have rephrased this line as follows:

The IWP is extracted along each pencil beam where radiative transfer simulations are performed. The atmospheric scenario has a higher spatial resolution than AMSU-B, so the simulated IWP are weighted according to the antenna pattern to obtain the AMSU-B IWP.

Reviewer comment:

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

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

We have added the following text:

This might contribute to the observed differences.

Reviewer comment:

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

Answer:

That’s really just how the data is stored, and probably not relevant. We have changed the text to:

The limb effect is minimal for the two viewing angles closest to nadir. The average brightness temperature for those angles is the reference.

Reviewer comment:

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?

C489

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

To clarify, we have added the following text here:

MHS-CPR IWP could still perfectly reproduce MHS-CPR IWP even considering the MHS radiometric noise, because this noise is part of the training data. If it would do so, CPR IWP might still be off by 40% compared with the true atmospheric IWP, but Fig. 10 would not show variability.

Reviewer comment:

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.

Answer:

To clarify and answer the reviewer's question, we have changed the text to:

For practical reasons, this subset consists of the MHS measurements for where collocations could be found;

Reviewer comment:

Page 842, line 11: Which steps in σ do you take?

C490

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

Steps of 0.1. We have added the following text:

taking steps of $\sigma=0.1$ K.

Reviewer comment:

Page 843 line 8–9: Do you use colocated 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 MHS? Please add some detail about this.

Answer:

It is the same number. At page 840, we have changed line 11 to:

Hence, we choose collocations where at least five CPR pixels are within 10 km of the nearest HIRS pixel.

and at page 843, we have added:

The number of collocations used for the neural net remains the same, because we already preselected the collocations so that at least five CPR pixels are less than 10 km from the nearest HIRS pixel centerpoint.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Reviewer comment:

Page 843 line 8–9: Why don't you use brightness temperature differences between HIRS channel 8 and HIRS channel 10 (12.47 μm)? This difference is very sensitive to thin cirrus.

Answer:

So far the work with HIRS was of an exploratory nature. We are grateful for the reviewers suggestion and we will try this out in the future. We have added a note about this in the conclusions.

Reviewer comment:

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

Answer:

We find it difficult to be sure about this by just looking at the scatter plot.

Reviewer comment:

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.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

As can be seen from the scatter plot, only a few hundred points were used in this test (15% of 2627). The retrieved IWP is divided in 40 bins. The ANN has a wet bias, so it may occur that there are no cases for low IWP, so that no error can be defined. Training an ANN is a random process and in this case, we necessarily use two different networks. Hence, it may occur that in one case, low IWP occur, but in the other case, it doesn't.

3 Technical corrections

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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

C493

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

Done.

Reviewer comment:

Title: “examples of use” instead of “usage examples”?

Answer:

We prefer the current title.

Reviewer comment:

Page 822 line 5: “onboard the CloudSat CPR” → “onboard CloudSat”.

Answer:

Done.

Reviewer comment:

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

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

Done.

Reviewer comment:

Page 823 line 15: “for the climate” –> “for climate”.

Answer:

We prefer “for the climate”.

Reviewer comment:

Page 823 line 16: “ the different General” –> “different General”.

Answer:

Done.

Reviewer comment:

Page 824 line 13: “as CloudSat and passive” –> “as CPR on CloudSat and passive”.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

Done (with explanation of acronym)

Reviewer comment:

Page 824 line 18: “the CloudSat” → “CloudSat CPR”.

Answer:

Done.

Reviewer comment:

Page 824 line 25: “between CloudSat” → “between CloudSat CPR”.

Answer:

Done.

Reviewer comment:

Page 825 line 5: “onboard the CloudSat” → “aboard CloudSat”.
C496

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Answer:

Changed to "... the CPR on-board CloudSat"

Reviewer comment:

Page 825 line 18: "A-train" -> "A-Train".

Answer:

Done.

Reviewer comment:

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".

Answer:

Done.

Reviewer comment:

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



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

Answer:

Done.

Reviewer comment:

Page 826 line 11: “It scans” → “It scans across-track”?

Answer:

Yes, done.

Reviewer comment:

Page 826 line 19: AAPP = ??

Answer:

ATOVS and AVHRR Pre-processing Package; definition added.

Reviewer comment:

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.

Answer:

Done.

Reviewer comment:

Page 827 line 4: “A scan” → “A HIRS scan”.

Answer:

Done.

Reviewer comment:

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.

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

Page 828 line 22: “true size” → “true pixel size”.

Answer:

Done.

Reviewer comment:

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

Answer:

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Interactive Discussion

Discussion Paper



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Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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

Answer:

Done

Reviewer comment:

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).”

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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Interactive Discussion

Discussion Paper



Page 830 line 25: “1 g m–2 ” → “1 g m–2 of ice”.

Answer:

Done.

Reviewer comment:

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

Answer:

Replaced by “scan lines”.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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Discussion Paper



Page 832 line 18: “subsattelite” -> “subsatellite”.

Answer:

Done.

Reviewer comment:

Page 832 line 19: “rougthly” -> “roughly”.

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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Discussion Paper



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

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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Interactive Discussion

Discussion Paper



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

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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

Answer:

Done, except on page 845 line 11, because we prefer the plural “neural networks” over the pular “ANNs”.

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Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

Page 844 line 10: “frecuencices” → “frecuencies”.

Answer:

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Discussion Paper



Done.

Reviewer comment:

Figure 2: “CloudSat” → “CPR”.

Answer:

Done.

Reviewer comment:

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

Answer:

We have added tick marks and changed the colour for no collocations to white.

Reviewer comment:

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 ?

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Discussion Paper



Answer:

Done.

Reviewer comment:

Figure 5: “of the all” → “of all”.

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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Discussion Paper



Figure 7: “CloudSat” → “CloudSat CPR”. “log IWP” → “log IWP/1 g m⁻²”. “The lines connecting from the boxes...”?? “plotted as outliers”?? Could you please explain the plot more clearly?

Answer:

We have changed the text to:

Modified boxplot of Ice Water Path and MHS channel 5 or AMSU-B channel 20 brightness temperature. Radiances are binned in ¹⁰ log IWP bins with a width of 0.1 log g/m². In each bin, the median brightness temperature is shown as a horizontal line. The upper and lower bars of the rectangle show the 1st and 3rd quartile (25th and 75th percentile). From the rectangles, dashed lines connect to the 1st and 99th percentile. All other points are defined as outliers and plotted as pluses. Collocations are shown in blue and simulations are shown in red.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

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 IWP.”

Answer:

Done.

Reviewer comment:

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

Answer:

Done.

Reviewer comment:

Figure 11: See remark about Fig. 9.

Answer:

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Discussion Paper



Done.

Reviewer comment:

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.”

Answer:

Done.

4 Other changes since the first manuscript

Apart from the changes suggested by both peer reviewers (see also our other Author Response), we have made the following changes:

- Page 826, line 11: removed “stored in the ATOVS data format”
- Page 830, line 5: added “The procedure described above is not the fastest possible (for example, point (d) could be optimised further) but with this algorithm, the bulk of the time running the code searching for collocations was spent on downloading files from a local server and decompressing them.”
- Page 832, line 14: added “considered in this study”
- Page 837, line 14: expanded acronym ECMWF

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- Page 846, line 1: fixed reference to Austin paper (published 2009, not 2008)
- Page 854, Fig. 4: corrected error, graph had only 30 days whereas January has 31

Please also note the supplement to this comment:

<http://www.atmos-meas-tech-discuss.net/3/C460/2010/amtd-3-C460-2010-supplement.pdf>

Interactive comment on Atmos. Meas. Tech. Discuss., 3, 821, 2010.

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