COLLOCATING SATELLITE-BASED RADAR AND RADIOMETER MEASUREMENTS – METHODOLOGY AND USAGE EXAMPLES

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ABSTRACT

Collocations between two satellite sensors are occasions where both sensors observe the same place at roughly the same time. We study collocations between the Microwave Humidity Sounder (MHS) on-board NOAA-18 and the Cloud Profiling Radar (CPR) on-board CloudSat. We present some statistical properties of the collocations. For 2007, we find approximately two and a half million MHS measurements with CPR pixels close to their centrepoints. We present some possible applications. We use the collocations to validate an operational Ice Water Path (IWP) product from MHS measurements, produced by the National Environment Satellite, Data and Information System (NESDIS) in the Microwave Surface and Precipitation Products System (MSPPS). IWP values from the CloudSat CPR are found to be significantly larger than those from the MSPPS. Finally, we use the collocations to train an Artificial Neural Network and describe how we can use it to develop a new MHS-based IWP product. The collocations described in the article are available for public use.

Key words: collocations; IWP; ice water path; AMSU; AMSU-B; MHS; CloudSat; neural network.

1. INTRODUCTION

Collocations between sensors on the same platform are commonly used (for example, see [FAS96, Ben00]), and collocating data from different satellite platforms has been done before as well. The A-Train constellation was motivated by the advantages of using a combination of measurements [SVB+02]. However, not much work has been published on actual collocation methods. The first peer-reviewed publication on the subject appears to be [NH09].

No literature exists that focusses on collocations between an active instrument and passive, operational instruments. However, such collocations have relevant applications. If we can use collocations between CloudSat CPR and NOAA-18 MHS to improve the operational microwave IWP retrieval, the advantages will last much beyond the lifetime of the A-Train satellites and have a much higher spatial coverage. Even passive microwave data from before CloudSat could be reprocessed with an improved algorithm.

This extended abstract summarises work described more extensively in [HBRJ10].

2. INSTRUMENTS

The Cloud Profiling Radar (CPR) is a nadir radar instrument (94 GHz) on-board the CloudSat satellite [SVB+02]. It has an Ice Water Path (IWP) product [AHS09] with a reported upper uncertainty limit of 40%. However, throughout this article, we assume CloudSat CPR to represent the truth.

The Advanced Microwave Sounding Unit-B (AMSU-B) and its successor the Microwave Humidity Sounder (MHS) are cross-track scanning microwave radiometers [SHSA95, KW07]. MHS channels 3–5 correspond to AMSU-B channels 18–20. The channels have centre frequenties of 183.31±1.00 GHz, ±3.00 GHz and ±7.00 GHz respectively (MHS channel 5 operates at 190.31 GHz). We use channels 3–5 because of the prominent water vapour spectral line at 183.31 GHz. We neglect the differences between AMSU-B and MHS. Because of its proximity to CloudSat, we focus on NOAA-18 and MHS for the collocations.

The sensor footprints are illustrated in Fig. 1.

More detailed information on the sensors can be found in [HBRJ10].

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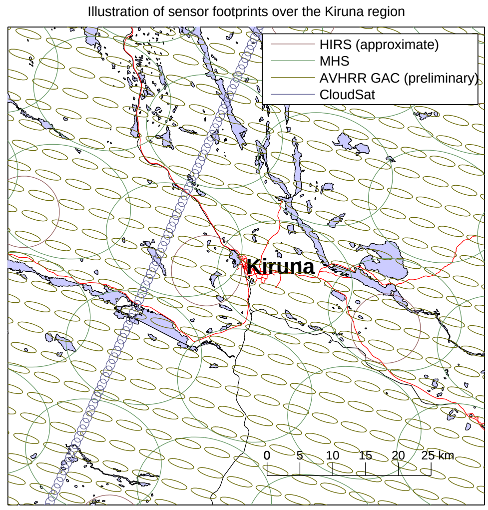

Figure 1. Footprint of the MHS, HIRS/4, AVHRR and CPR sensors. Map data ©OpenStreetMap contributors, CC-BY-SA.

3. FINDING COLLOCATIONS

A collocation occurs when the sensors observe exactly the same place at approximately the same time.

As shown in Fig. 1, an MHS footprint is an order of magnitude larger than a CPR footprint and HIRS measurements are not on the same grid as MHS measurements.

We create two collocated datasets. In the first dataset, there is an entry for each CloudSat measurement collocating with an MHS measurement, so that there can be many collocations for the same MHS pixel. In the second dataset, each collocation has a unique MHS measurement and CPR pixels are averaged. The total area covered by the CPR pixels is much smaller than the MHS footprint area (see Sect. 3.2).

Both datasets are available for public use.

More information, such as the procedure used to find the collocations, can be found in [HBRJ10].

3.1. Collocation statistics

We have located collocations for the period between 15 June 2006 13:12 and 4 October 2008 10:34. With a maximum distance of 7.5 km and counting the MHS pixels, we have 2 669 135 collocations, including 26 410 within 30 degrees of the equator and within 1 degree of nadir.

Figure 2 shows the latitudes at which collocations occur between the CloudSat CPR and the MHS/AMSU-B on different satellites.

Figure 3 shows at which angles and latitudes the collocations occur.

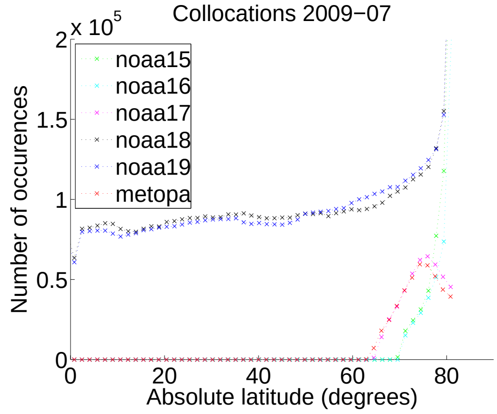

Figure 2. A histogram of the number of CPR pixels within 15 km and within 15 min of AMSU-B or MHS.

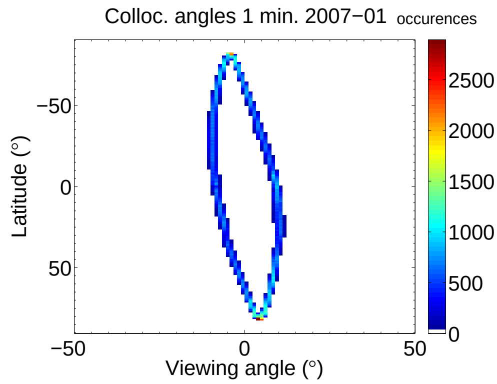

Figure 3. This two-dimensional histogram shows at which angles the collocations between the NOAA-18 MHS and the CloudSat CPR occured in January 2007. The figure shows collocations with a maximum time interval of 1 min.

Figure 4 shows a time series of the number of collocations per hour in January 2007.

3.2. Sampling effects

As shown in Fig. 1, an MHS footprint is an order of magnitude larger than a CPR footprint. One CPR pixel covers at most 0.65% of an MHS pixel, and the total area of CPR pixels inside MHS is still less than 10%.

Statistics like those shown in Fig. 5 can be used to select homogeneous collocations.

The sampling effects are described in detail in [HBRJ10].

4. APPLICATIONS

Collocations can be used in many different ways. This section presents some possible applications of colloca-

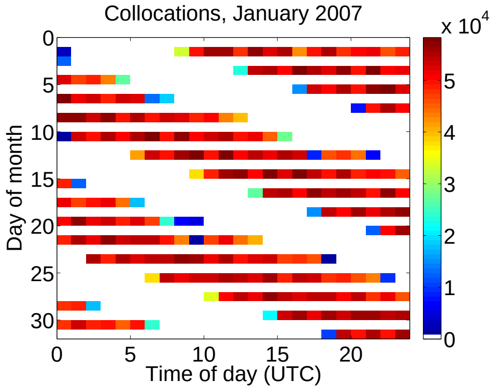

Figure 4. Number of collocations per hour in January 2007. The vertical axis shows the day of the month. The horizontal axis shows the universal time.

tions between CloudSat CPR and NOAA-18 MHS. One more application is described in [HBRJ10].

4.1. Comparison with NESDIS IWP

The National Environment Satellite, Data and Information Service (NESDIS) publishes an operational IWP product from MHS measurements in the Microwave Surface and Precipitation Products System (MSPPS), described in [ZW02].

CloudSat IWP has a systematic uncertainty of up to 40% [AHS09]. Judging from the available data, the detection limit for CloudSat IWP is 1 $\mathrm{g\,m^{-2}}$.

Figure 6 shows a comparison of the NESDIS MSPPS IWP with the CloudSat IWP. It shows that the NESDIS IWP is systematically smaller than the CPR IWP.

One way to obtain such a product is by using a neural network, described later in the article.

This application is described in more detail in [HBRJ10].

4.2. Developing a retrieval using neural nets

An artificial neural network (ANN) is an interconnected assembly of processing units called neurons (e.g. [JEM03]). We use an ANN to characterise the mapping between MHS radiances and the CPR IWP, and then use the trained ANN to retrieve IWP from the MHS measurements. We call this retrieval MHS-CPR IWP.

The neural network approach described below is in the exploration phase and will be developed further.

We select a subset of 2627 collocations that provide a relatively homogeneous dataset. The selection and the procedure are described in detail in [HBRJ10].

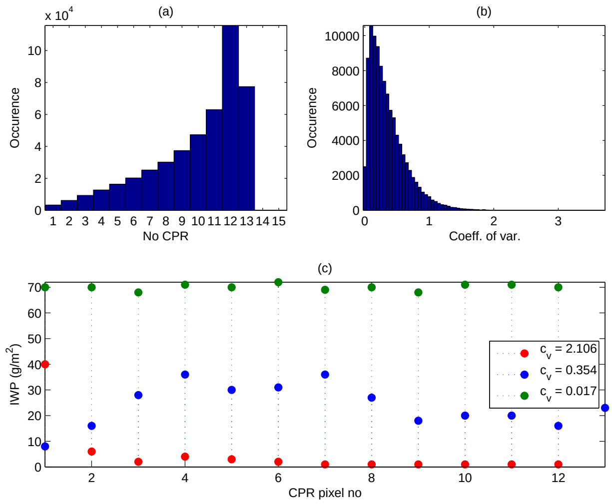

Figure 5. Some collocation properties for 2007. **(a)** *shows a histogram of the number of CPR pixels that fit inside a MHS pixel (circular with a 7.5 km radius).* **(b)** *shows a histogram for the coefficient of variation of all collocations that contain only cloudy pixels.* **(c)** *shows examples of how CPR IWP may be distributed inside a MHS pixel.*

So far, the neural network is only applicable to the tropics.

To compensate for the limb effect, we correct the brightness temperatures before we input them to the network as described in [HBRJ10].

In Fig. 7 we show an example of how a NN IWP product might look like. The data is for 1 January 2008. The left panels show the MHS brightness temperatures between 08:56 and 19:02 UTC, the right panel shows the IWP retrieved by the neural network.

An error analysis is described in [HBRJ10]. In [HBRJ10], we also explore the effect of adding HIRS.

5. CONCLUSIONS

Collocations between NOAA-18 MHS and Cloudsat CPR are frequent and globally distributed and have various applications. They can be used to compare different IWP products. We have shows that they can be used to train an Artificial Neural Network to develop a new IWP product. All the applications can be expanded upon and many other applications can be developed. These and other issues will be adressed in further research.

The collocations are available for public use.

More information is available in [HBRJ10].

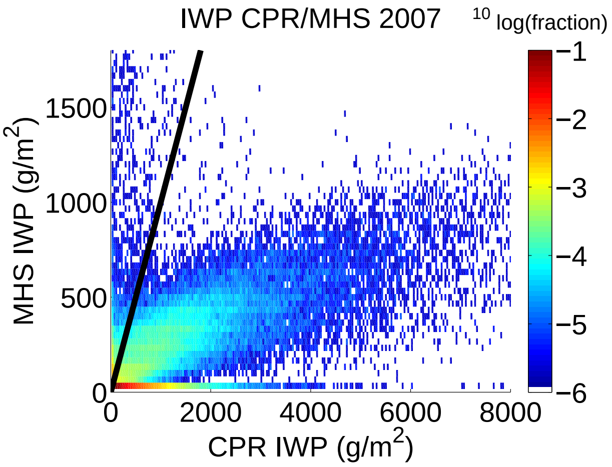

Figure 6. Two-dimensional histogram of CloudSat CPR Ice Water Path (averaged over an AMSU pixel) and NOAA NESDIS MSPPS IWP, for all collocations in the year 2007. The figure is similar to a scatter plot, but it shows the density of points rather than the actual points. Only measurements where either value is nonzero are shown. The black line shows the ideal case. The colour scale is logarithmic. See text for a discussion.

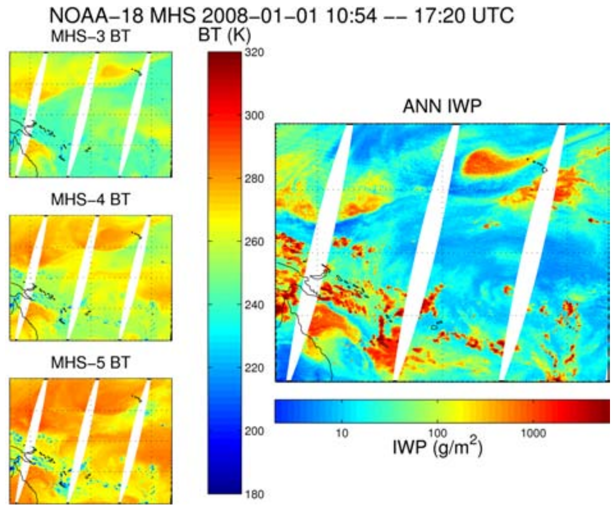

Figure 7. The neural network (see text) can be used to retrieve IWP from radiances. The figure shows observations by NOAA-18 in the descending node on 1 January 2008 between 10:54 and 17:20 UTC (local time during the night). The left panels show the brightness temperatures as observed by the MHS channels 3–5. The right panel shows the IWP as generated with the neural network as described in the text. Cold areas in the left panel correspond to wet areas in the right panel.

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