COMPARISON OF THE OPTIMAL CLOUD ANALYSIS PRODUCT (OCA) AND THE GOES-R ABI CLOUD HEIGHT ALGORITHM (ACHA) CLOUD TOP PRESSURES FOR AMVS

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Abstract

Atmospheric Motion Vectors (AMVs) are an important source of satellite data for assimilation into Numerical Weather Prediction (NWP) models. A large driver of the accuracy of AMVs are the heights assigned to each vector. In recent years, AMV applications are relying more and more on the cloud heights generated from external cloud height algorithms, including those participating in the International Cloud Working Group (ICWG). AMV applications provide a direct link to the cloud height products and the NWP community.

While cloud height comparisons have been a common activity in the past Cloud Retrieval and Evaluation Workshops (CREW), the AMV application only uses a sub-set of cloud heights. This subset usually consists of cloud edges and other features that are identifiable targets in the AMV tracking schemes.

To make a relevant analysis, we will use an AMV algorithm to select pixels which would serve as AMV targets and restrict our analysis to those pixels. We will use the NOAA/CIMSS AMV software and use 1DVAR heights from NOAA (ACHA) and EUMETSAT (OCA). Our goal will be to compare the cloud height performance for the AMV-relevant pixels. Another aspect of this work is to compare the cloud height uncertainty estimates and other meta-data. We intend to collaborate with the International Winds Working Group (IWWG) and work towards standard and relevant definitions of our products and their meta-data.

INTRODUCTION

AMV generation is increasingly reliant of cloud top pressure (CTP) generated from separate cloud retrieval algorithms. Eumetsat's OCA has been operational since the release of the Meteorological Product Extraction Facility (MPEF) Release 2.1 on April 1, 2015. The current version is MPEF Release 2.2. The Japanese Meteorology Agency (JMA) is also running an Optimal Estimation (OE) algorithm for their operational AMV product. NOAA is running VIIRS polar AMVs with the GOES-R ABI algorithm, which uses an upstream OE algorithm (ACHA) for height assignment. All satellites that NOAA uses in AMV processing will be transitioned to the ABI algorithm in the near future.

Groups such as the International Cloud Working Group (ICWG), formerly the Cloud Retrieval Evaluation Workshop (CREW) compare cloud products at the pixel level, but do not focus on the subset of pixels that are used as AMV tracers. Adding similar ICWG analysis to the AMVs will be a valuable tool moving forward. The 1st biennial workshop of the ICWG was held in Lille, France from May 17 – 20, 2016. One of their key issues is the assessment of cloud parameter retrievals and their uncertainty estimates. The ICWG Uncertainty group took an action to expand their comparisons to the uncertainty estimates. Beyond product performance, the

potential use of diagnostic parameters like the CTP uncertainty are important to investigate for usage by AMV algorithms and their users.

Prototype analysis software has been written in IDL to allow a study of the impact of CTP performance on AMV applications. ACHA (NOAA) and OCA (Eumetsat), two OE algorithms are the first products to test out the analysis concepts. Future work includes extending the analysis to other pixel level cloud algorithms and link back to the CTP work being done within the ICWG.

AMV METHOD

OCA GRIB2 files were downloaded from the Eumetsat archive (free account needed) at hourly time steps for the month of October 2015. Software was developed to convert the OCA GRIB2 files into HDF4. The software framework that runs ACHA requires most files in HDF4. Matching hourly ACHA cloud products were generated. The matching OCA fields were read into auxiliary variables to create one level2 HDF4 file that contains both algorithms output.

A new branch of the GOES-R ABI winds software was developed to read pre-existing cloud information from a static cloud level2 HDF4 file. The AMVs were run once with cloud information from ACHA, and then again with cloud products from OCA. This method ensured that the same tracking software was used between the ACHA and OCA CTP pixels. Table 1 shows the cloud products read from the static file.

Cloud Algorithm	Product Used
ACHA	Cloud Mask
ACHA, OCA	Cloud Top Pressure – Layer 1
ACHA	Cloud Height Quality Flags
ACHA	Cloud Top Temperature
ACHA	Cloud Top Height
ACHA, OCA	Cloud Phase
ACHA	Cloud Type
ACHA	Inversion Flag
ACHA, OCA	Cloud Top Pressure Uncertainty – Layer 1
ACHA	Cloud Top Temperature Uncertainty – Layer 1
ACHA, OCA	Cost

Table 1: **Cloud products read from static HDF4 files, and used in the AMV software.**

REVIEW OF OCA AND ACHA

OCA and ACHA are both OE algorithms. Each uses a different fast radiative transfer model, and different NWP ancillary datasets. Both algorithms attempt to provide solutions for multi-layer clouds. A cost value is also produced which can indicate failures within the retrieval. Even though both algorithms are OE, there are several differences that are noted in Table 2. The table assumes that input satellite data is from Meteosat-10 SEVIRI.

	OCA	ACHA
Input	0.6, 0.8, 1.6, 3.9, 6.2, 7.3, 8.7, 9.7, 10.8, 12.0, 13.4 μm + cloud mask	6.2, 10.8, 13.4 μm + cloud mask + cloud phase + multi-layer flag
Output	Cloud Optical Thickness (COT), Cloud Top Pressure (CTP), Cloud Effective Radius (CRE), Cloud Phase, COT*, CTP*	Cloud Top Temperature (CTT), Cloud Emissivity (CEMS), β (a microphysical parameter), CTT*
Derived Output		CTP, Cloud Top Height (CTH), COT, CRE, CTP*, CTH*
Uncertainties	CTP uncertainty generated directly from the OE matrices	CTP uncertainty calculated from OE CTT uncertainties and factors based on lapse rates

Table 2: **OE differences between OCA and ACHA. COT*, CTP*, CTH* represent the value of the lower cloud when a multilayer retrieval has been done. Note: ACHA input is always 2 or 3 channels in the infrared spectrum.**

PIXEL LEVEL COMPARISONS

ACHA and OCA data for the month of October 2015 were used to help generate AMVs from 15 minute Meteosat-10 SEVIRI triplets, centered on the hour. Along with CTP, each algorithm also makes CTP uncertainties. Figure 1 shows an example of CTP and CTP uncertainty for each algorithm.
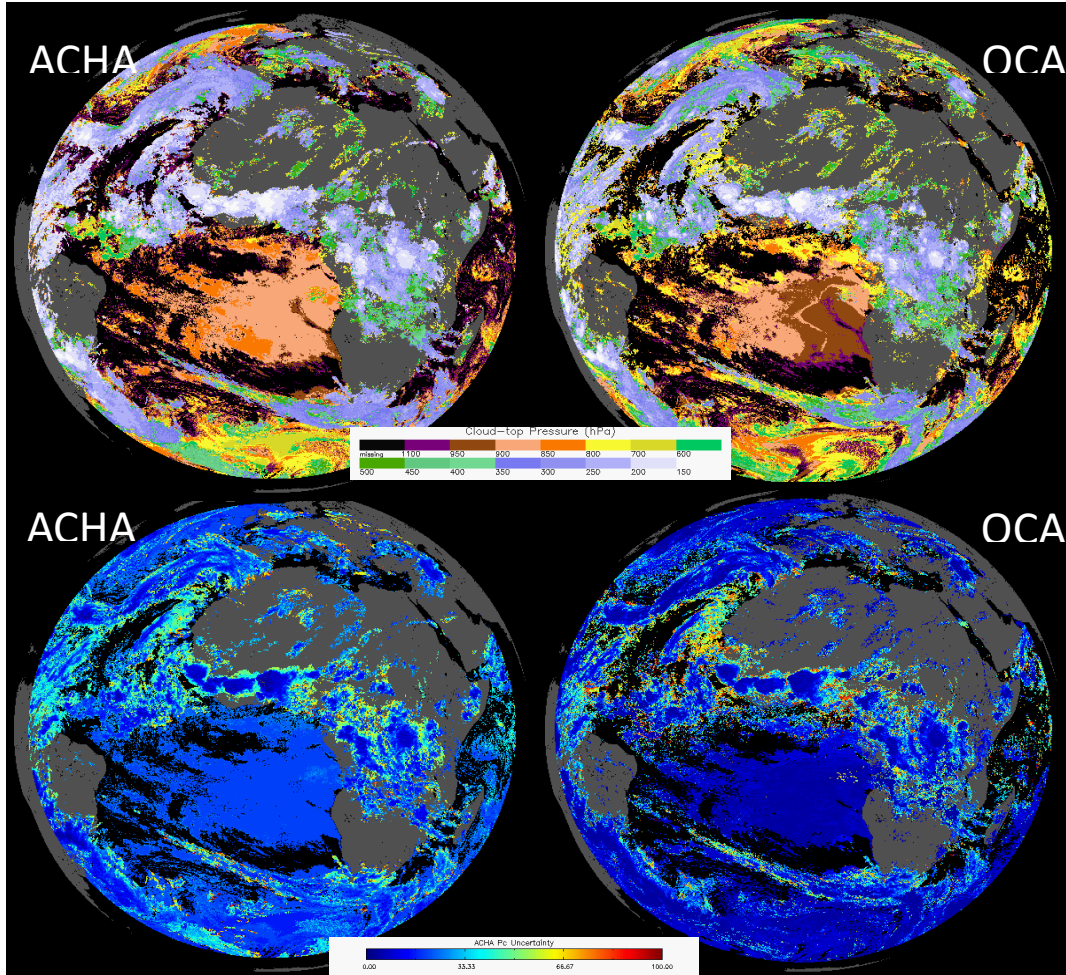

Figure 1: CTP (hPa) top, and CTP uncertainty (hPa), bottom, from Meteosat-10 SEVIRI data from October 11, 2015.

A scatterplot of CTP uncertainties is shown in Figure 2. The plot shows ACHA (y-axis) versus OCA (x-axis) for Meteosat-10 SEVIRI data on October 11, 2015. All cloudy pixels are used and not limited to AMV targets. The left image shows the scatterplot during the day and the right image during the night. The correlation is a bit greater at night. ACHA is very correlated with cloud emissivity both day and night, while OCA is correlated more at night. ACHA CTP uncertainties are consistent both day and night, whereas OCA uncertainties are lower during the daytime. The uncertainties should vary between algorithms, as OCA uses more satellite channels, some of them in the visible and near infrared spectrum. CTP uncertainties will become an important topic within the International Cloud Working Group (ICWG) as they work towards standardizing this for AMV applications.
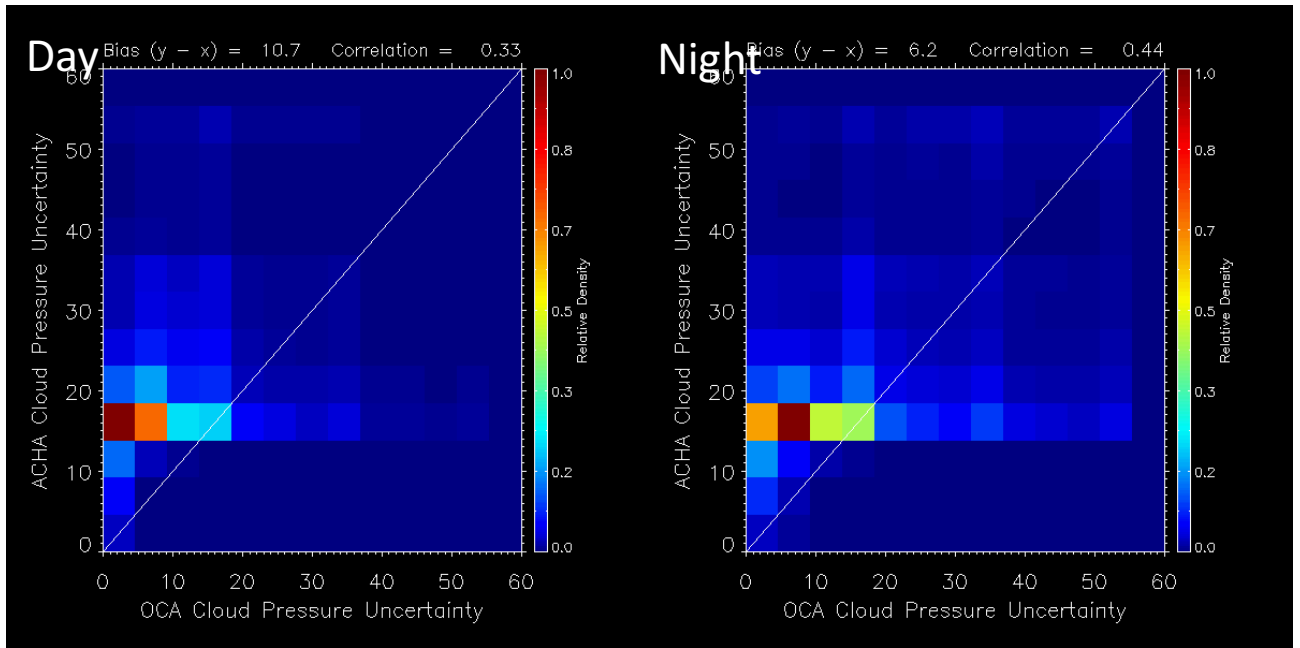
Figure 2: **Scatter plots of CTP uncertainties between OCA and ACHA for October 11, 2015.**

CALIPSO COMPARISONS AT THE PIXEL LEVEL

One of the main validation tools for pixel level cloud heights is through comparisons with CALIPSO. Figure 3 shows the results of collocating ACHA/OCA/CALIPSO cloudy pixels into a homogeneous sample. As in Figures 1 and 2, all cloud pixels were used. The image on the left is the normalized counts showing to peaks in CALIPSO data. One around 200 hPa, and the other at 900 hPa. OCA and ACHA comparisons to CALIPSO are very similar. Both methods are lower (larger pressures) than CALIPSO at high altitudes, and higher (smaller pressures) at low altitudes (second and third images from the left). In general, ACHA is higher in the atmosphere than OCA at all levels (far right plot). Filtering on shared optical depths greater than one, and demanding that the phases are matched (not shown) shifted the count distribution to the lower levels. However, the impact on bias shown in Figure 3 was small.
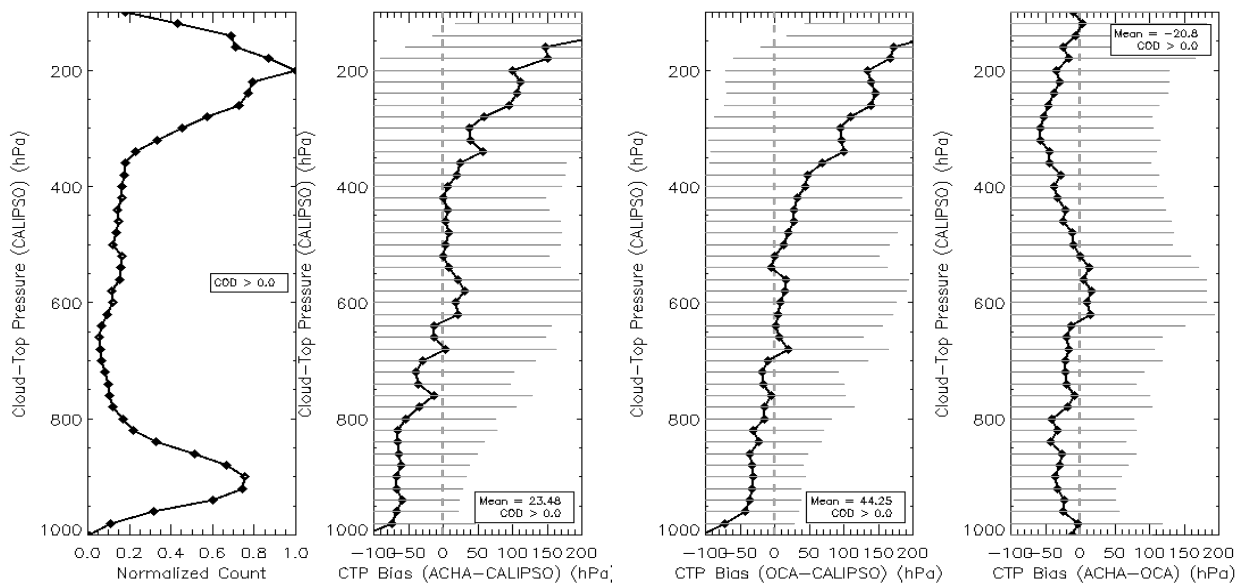

Figure 3: **Pixel level CTP comparisons between ACHA/OCA/CALIPSO. Far left plot shows the two distinct peaks in pressure (hPa) in the collocations. The middle two images show ACHA minus CALIPSO, and OCA minus CALIPSO comparisons. The horizontal lines represent the standard deviation. Far right image compares differences between ACHA and OCA.**

AMV CLOUD PRESSURE COMPARISONS

As with all other AMV software, the GOES-R code uses a collection of cloud pixels to form a representative tracer height. Unlike the cloud pixel comparisons shown above, the AMV figures are shown as single channel plots. Software was written to mimic Figure 3 for the AMVs. However, only a few AMVs per dataset were matched with CALIPSO data. Although not shown here, the ACHA heights were generally higher in the atmosphere than the OCA AMVs. This simply affirms what is shown in the far right plot in Figure 3. Figure 4 shows a set of plots comparing collocated 11 μm AMVs from ACHA and OCA over all of the datasets from October 11, 2015. The profile of CTP versus counts shows both peaks have shifted downward in the atmosphere when compared to Figure 3. This is an expected result, described in Wayne Bresky's journal article. The second image from the left is simply a collocated difference image of CTP heights using the collocated AMVs. In the upper level peak, the ACHA AMVs are higher in the atmosphere than OCA. In the lower levels the differences are much smaller. The software written for this plot can be used to look at any variable in the output file. For the last two plots, the AMV height assignment bias from model best-fit pressure was examined. The best-fit pressure level is where the vector difference between the observed AMV and the model background is minimized. The ACHA minus best-fit plot clearly shows a high bias in the upper levels. It is much smaller in the OCA minus best-fit plot. Both ACHA and OCA exhibit a high bias in the first peak of the low-levels.
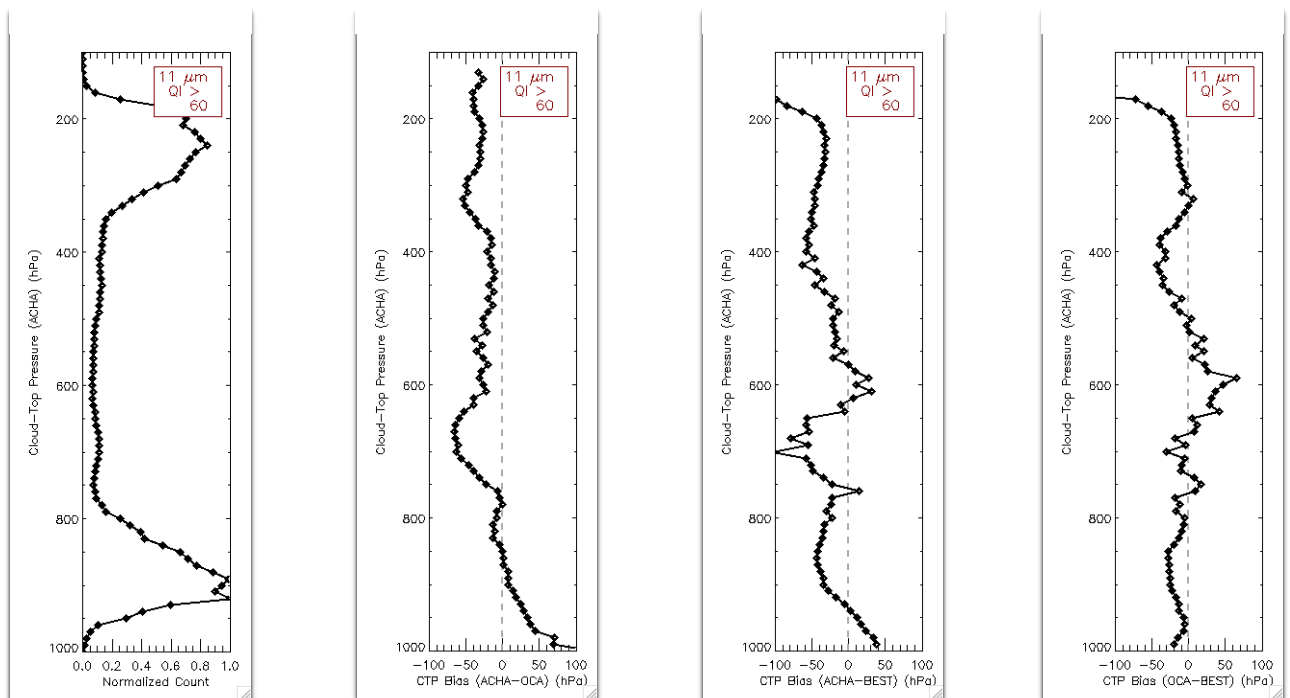

Figure 4: **Plots of collocated ACHA and OCA 11 μm AMVs. Left plot is a histogram of collocated AMVS. The second plot shows the CTP bias between ACHA and OCA AMVS. The last two plots are bias profiles of CTP and the level of best-fit of the model background.**

You can see these differences from the second plot in Figure 4 mapped onto the Meteosat-10 SEVIRI grid in Figure 5. Negative bias represents ACHA higher in the atmosphere than the OCA AMVs.
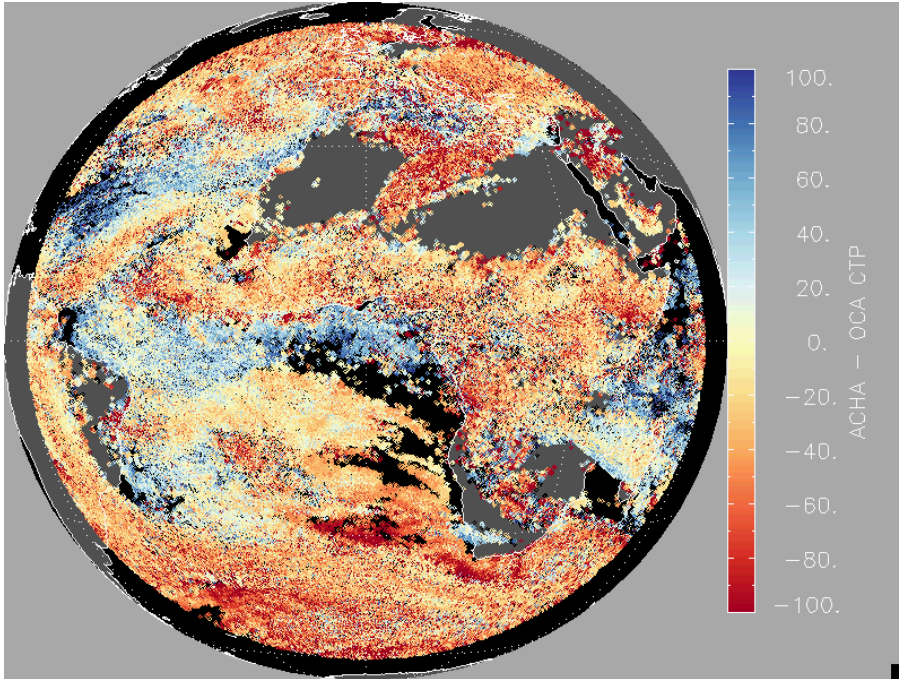
Figure 5: Graphical representation of the second plot in Figure 4, using all AMV sets from October 11, 2015.

This analysis can also be used for the WV channel. The GOES-R code allows only upper level AMVs in the WV channels. The WV AMV differences between ACHA and OCA are smaller than in the upper levels of the 11 μm AMVs (Second plot in Figure 4).
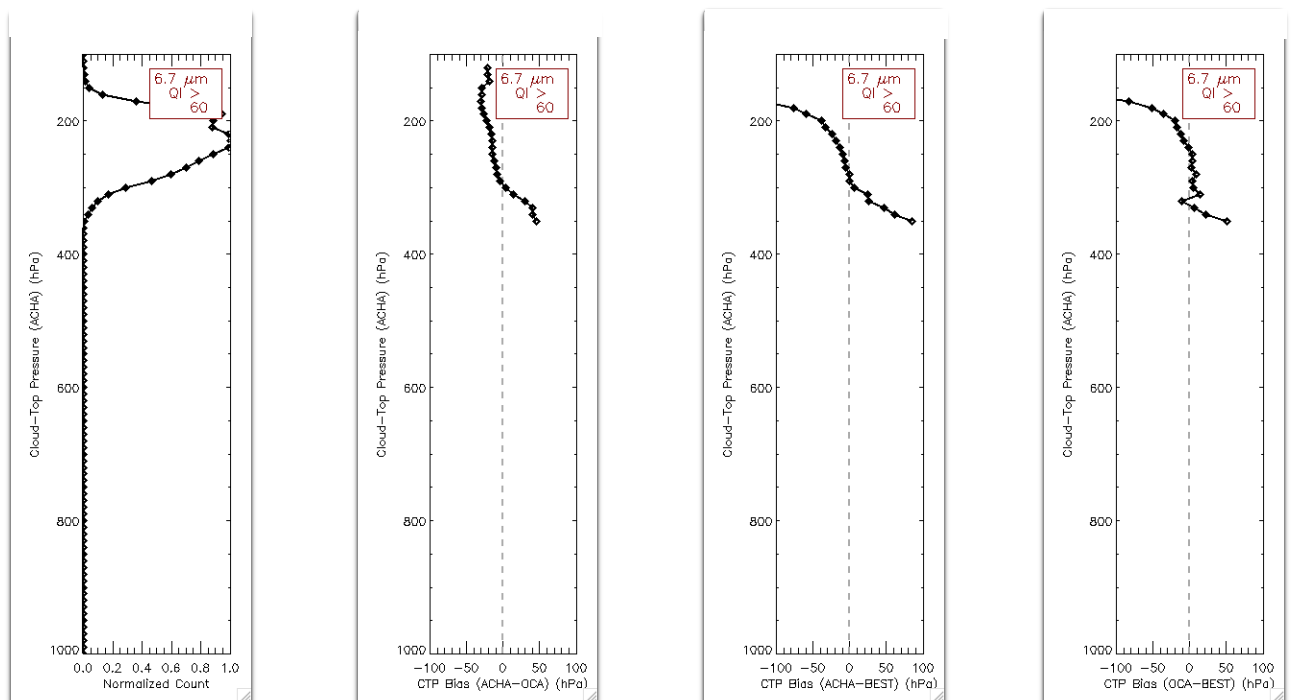

Figure 6: Plots of collocated ACHA and OCA 6.2 μm AMVs. Left plot is a histogram of collocated AMVS. The second plot shows the CTP bias between ACHA and OCA AMVS. The last two plots are bias profiles of CTP and the level of best-fit of the model background.
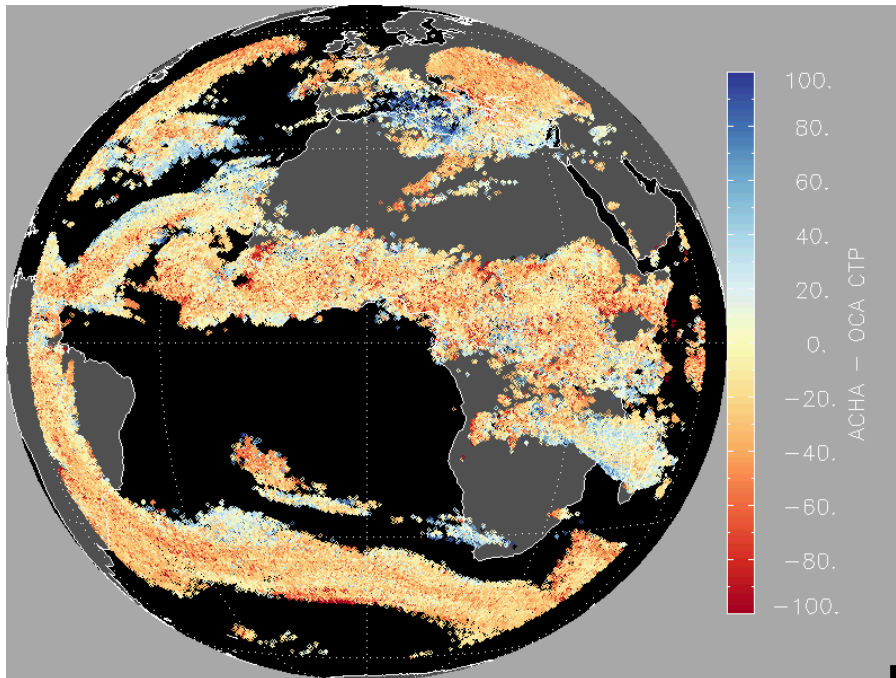
Figure 7: Graphical representation of the second plot in Figure 6, using all AMV sets from October 11, 2015.

SUMMARY

An initial analysis package has been developed to help facilitate progress on improving cloud height products for AMV applications. OCA and ACHA are two pixel-based cloud algorithms used in this study, but the analysis can be expanded to any pixel level CTP product. Preliminary finds indicate that OCA and ACHA are similar, but the observed differences warrant future study. The CTP uncertainties show correlation but their use in AMV quality screening is not obvious. The CTP uncertainty product will become important to the ICWG group moving forward.

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