P3.40 AN EVALUATION OF SEVERAL YEARS OF CIMSS AND NESDIS GOES SOUNDER DATA

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1. INTRODUCTION

At The Cooperative Institute for Meteorological Satellite Studies (CIMSS), vertical temperature and moisture profiles retrieved from GOES Sounder radiances (retrievals) have been produced and compared to radiosondes since 1995. In addition, National Environmental Satellite, Data, and Information Service (NESDIS) operational retrievals have also been compared with radiosondes. Comparision of these two rich datasets allows for extensive evaluation of past performance, and could lead to ideas for future retrieval improvements.

The main focus of this paper is to compare these two sets of retrievals with collocated, verifying radiosonde data. Due to space limitations, only Total Precipitable Water (TPW) will be examined; however, several temperature and moisture parameters will be examined at the conference. The data will be analyzed by month and season, by time (00UTC vs. 12UTC), by region (north vs. south, etc.), and by sensor (GOES-E vs. GOES-W). Moreover, an evaluation of one of the more important components of the retrieval process, the bias adjustment of the measured GOES radiances, will also be undertaken. The differences between the adjustments used in the CIMSS and NESDIS retrievals will be outlined and compared explicitly for Sounder band 5 (13.4µm) here, but will be expanded to include numerous Sounder bands at the conference.

2. GOES RETRIEVALS OF TEMPERATURE AND MOISTURE

Radiance data from the Sounder instruments aboard the GOES-I/M series of spacecraft have been available since mid-1994 (Menzel and Purdom 1994). This information can be used in a number of different ways; one of its uses is as a major component in deriving vertical profiles of temperature and moisture (satellite retrievals). For the last several years, GOES retrievals at both CIMSS and NESDIS (designated as OPS) have been produced using a nonlinear physical retrieval algorithm (Ma et al. 1999). Briefly, this algorithm uses GOES Sounder cloud-free radiances in a number of spectral bands that have been averaged over 1-N Fields of View (FOV) to adjust initial guess vertical profiles of temperature and moisture. At CIMSS, the averaging is done within a 3 X 3 matrix of FOVs (N<=9), while the NESDIS operational retrievals are produced using a 5 X 5 FOV matrix (N<=25). Since the nominal horizontal resolution of a GOES Sounder FOV is approximately 10km at the sub-satellite point (Menzel and Purdom 1994), the nominal dimensions of the CIMSS and NESDIS retrievals are approximately 30 X 30 and 50 X 50 km, respectively.

As part of the physical retrieval process, an adjustment to the input radiances is necessary to account for errors in both the radiative transfer model and instrument calibration (Ma et al. 1999). This correction is known as the radiance bias adjustment. The adjustment is computed differently for the OPS and CIMSS retrievals. The OPS retrievals use a method known as "shrinkage estimation" (Schmit 1996), a regression approach that involves using 26 predictors to determine an hourly bias adjustment to apply in each Sounder channel.

On the other hand, retrievals produced at CIMSS now employ a somewhat simpler approach to bias adjustment. Not only are the number of predictors reduced from 26 to 5, the regression coefficients need only be computed once every several months. The simpler approach has been made possible because of expanded GOES radiance ground processing that resulted in more accurate calibration of radiance data (Weinreb 1997).

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3. RETRIEVAL AND BIAS CORRECTION RESULTS

In this work, several years of GOES retrieval results from both CIMSS and NESDIS are examined. The examinations are conducted using two approaches: 1) comparisons of retrieval parameters, such as precipitable water and temperature, with the same from verifying radiosonde data, and 2) comparisons of the radiance bias adjustments made at CIMSS and NESDIS. The overall period of study for GOES-8 ranges from January 1998 through June 2001, while the same for GOES-10 ranges from January 1999 through June 2001. In the interest of brevity, our discussion will focus on comparing retrieval Total Precipitable Water vapor (TPW) with collocated radiosonde data. Previous work has shown that the nonlinear retrieval algorithm makes a larger adjustment to the guess moisture profile than the guess temperature profile (Ma et al. 1999).

3.1. Comparisons of retrieval parameters with radiosondes

Table 1 shows retrieval versus radiosonde bulk statistics for both the CIMSS and OPS retrievals, further subdivided by guess and retrieval, as well as retrieval time. These datasets have been constructed by requiring that each retrieval be collocated within approximately 0.1 degrees latitude/longitude (L/L) with a nearby radiosonde. The number of collocation matches (N) is larger for the CIMSS retrievals than the OPS retrievals because of the different retrieval processing box sizes. Looking first at the GOES-8 bulk statistics, one can see that the bias (GOES minus RAOB) is always negative. Furthermore, the standard deviation (SD) is reduced for all 4 sets of GOES-8 retrievals (00Z CIMSS, 12Z CIMSS, 00Z OPS, 12Z OPS) compared to their respective guesses. The 12Z retrieval SD values tend to be larger than their 00Z counterparts (3.22 versus 3.04 for CIMSS retrieval TPW, 3.29 versus 3.05 for OPS retrieval TPW). Looking at the average TPW data, there is a tendency for the CIMSS guesses and retrievals to contain less moisture than the OPS guesses and retrievals. Perhaps this is related to the different retrieval box sizes.

Turning our attention now to the GOES-10 bulk statistics, note that the number of radiosonde matches is approximately one-quarter of those from GOES-8. This is because less of the GOES-10 data is over CONUS. Also note how both the bias and SD values are reduced compared to the GOES-8 data. This is probably not too surprising, considering the average TPW values for GOES-10 are significantly smaller than the GOES-8 data. However, it is also interesting to note that the change in TPW bias when comparing the guess and retrieval data more often has the proper sign (i.e., the retrieved TPW is closer to the collocated radiosonde TPW than the guess) for GOES-10 when compared to GOES-8.

Table 1. Retrieval versus radiosonde bulk statistics. Collocation distance is approximately 0.1 degrees latitude/longitude. Minimum clear FOVs is 4. BIAS, SD and AVG values are in mm.

DATASET	PERIOD	BIAS	SD	AVG GUESS / RET TPW	AVG RAOB TPW	CC	N
00Z CIMSS G-8 TPW guess	1/98-6/01	-0.62	3.15	16.25	16.88	0.959	2260
00Z CIMSS G-8 TPW retrieval	1/98-6/01	-0.64	3.04	16.23	16.88	0.961	2260
12Z CIMSS G-8 TPW guess	1/98-6/01	-1.10	3.39	16.51	17.61	0.957	1870
12Z CIMSS G-8 TPW retrieval	1/98-6/01	-0.89	3.22	16.72	17.61	0.961	1870
00Z OPS G-8 TPW guess	1/98-6/01	-0.23	3.33	17.68	17.91	0.956	750
00Z OPS G-8 TPW retrieval	1/98-6/01	-0.62	3.05	17.29	17.91	0.963	750
12Z OPS G-8 TPW guess	1/98-6/01	-0.61	3.38	17.65	18.26	0.963	679
12Z OPS G-8 TPW retrieval	1/98-6/01	-1.11	3.29	17.15	18.26	0.965	679
00Z CIMSS G-10 TPW guess	1/99-6/01	-0.40	2.62	10.00	10.40	0.906	630
00Z CIMSS G-10 TPW retrieval	1/99-6/01	-0.35	2.05	10.05	10.40	0.944	630
12Z CIMSS G-10 TPW guess	1/99-6/01	-0.86	2.73	11.06	11.92	0.925	442
12Z CIMSS G-10 TPW retrieval	1/99-6/01	-0.41	2.56	11.51	11.92	0.936	442
00Z OPS G-10 TPW guess	1/99-6/01	-0.11	2.59	12.17	12.29	0.928	143
00Z OPS G-10 TPW retrieval	1/99-6/01	0.12	2.46	12.41	12.29	0.935	143
12Z OPS G-10 TPW guess	1/99-6/01	-0.76	2.66	10.72	11.48	0.900	170
12Z OPS G-10 TPW retrieval	1/99-6/01	-0.49	2.46	10.99	11.48	0.914	170

Finally, the correlation coefficients (CC) are also smaller for GOES-10 than for GOES-8, perhaps showing that the GOES-10 averaged radiances tend to show a little less sensitivity to the first guess than the GOES-8 radiances.

In all subsequent results, the input data to the statistics computations are filtered twice. First, retrievals are only used in the computations if they are collocated within approximately 0.5 degrees L/L of a nearby radiosonde. This initial filtering procedure produces CIMSS/RAOB and OPS/RAOB collocation files. Then, the CIMSS/RAOB and OPS/RAOB matches are themselves subjected to the same 0.5 degrees L/L collocation procedure, as well as a 1 hour time collocation threshold. This results in one final file of matches, with all retrieval/RAOB matches being collocated within 0.5 degrees L/L, and the CIMSS and OPS retrievals themselves also being collocated within 0.5 degrees L/L. The intent is to compare CIMSS and OPS retrievals at very similar locations, while still maintaining a reasonably large dataset for the statistics.

Figure 1 shows a time series of GOES-8 00UTC and 12UTC combined TPW retrieval versus radiosonde bias for the CIMSS and OPS retrievals. Note the overwhelming tendency for negative biases, in agreement with Table 1 above. This may be demonstrating a weakness of coarse spectral resolution radiometers to detect low-level moisture. Also, the biases for both the CIMSS and OPS retrievals are maximized, in terms of largest dry bias versus the radiosondes, during the warmest and most moist summer months, and minimized during the cooler/dryer months. The same warm/moist and cool/dry seasonal tendencies also exist for GOES-10 (not shown). Furthermore, comparing the CIMSS and OPS biases to each other, one can see an interesting shift that occurred about July 2000. Prior to that time, the CIMSS biases tended to be closer to zero than the OPS retrievals, while after that point the OPS retrieval biases were closer to 0. This may be an indication of needing to update the CIMSS radiance adjustment database.

Figure 2 depicts a geographical distribution of CIMSS GOES-8 and GOES-10 combined 00UTC and 12UTC TPW bias at radiosonde locations. As one might expect, there are more negative than positive bias values. No clear regional bias tendencies are apparent, although pockets of positive bias exist in the Upper Midwest, along the

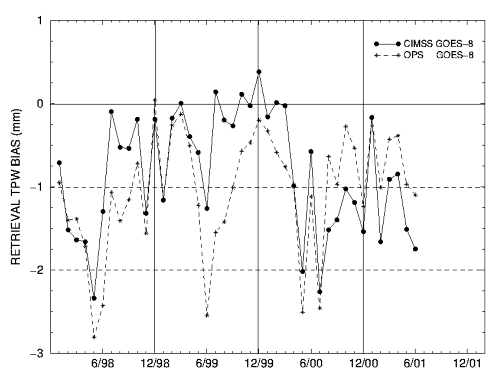

Fig. 1. GOES-8 CIMSS and OPS monthly, combined 00UTC and 12UTC TPW bias. Period is from January 1998 through June 2001.

eastern seaboard, along the Gulf coast, and over Mexico. Note also the large (in magnitude) negative biases in southern Texas. Similar distributions of bias are seen in Fig. 3 for the OPS retrievals, with an additional region of positive bias in the Pacific Northwest, and even larger negative biases in southern Texas (-4.45 mm versus -3.46 mm). More detailed study is required to determine the source of these large negative biases.

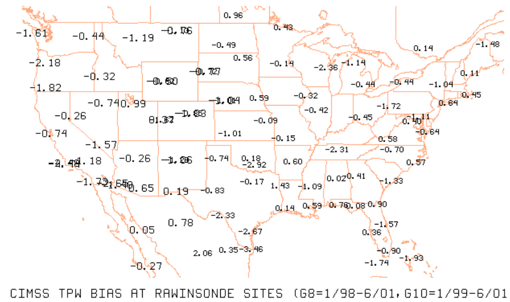

Fig. 2. CIMSS combined 00UTC and 12UTC retrieval TPW bias at radiosonde locations for GOES-8 (January 1998 – June 2001) and GOES-10 (January 1999 – June 2001). The larger numeric fonts (western portion) represent GOES-10 data.

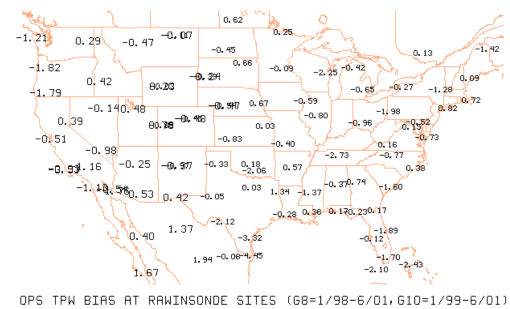

Fig. 3. As in Fig. 2 but for OPS retrievals.

3.2. Comparisons of bias-corrected radiances with radiosondes

As mentioned above, a GOES Sounder radiance bias adjustment in each channel is vital for producing satellite retrievals of temperature and moisture via a physical retrieval algorithm (Ma et al. 1999). To examine the results of the bias adjustment procedures used in the last several years at CIMSS and NESDIS, we have selected band 5 (13.4μm), a channel used in the retrieval of both temperature and moisture. Radiation in this band eminates mainly from the lower troposphere and surface (Menzel et al. 1998).

Figure 4 shows a time series of CIMSS monthly-averaged band 5 retrieval brightness temperatures for the period January 1998 – June

2001. The most obvious feature is the seasonal cycle. In the chart, the lowest average brightness temperatures are always the cloud-cleared, 3 X 3 FOV- averaged values, with the bias-corrected values being slightly warmer. The collocated radiosonde data are the warmest values. It can be seen that the bias adjustment is always towards the collocated radiosonde data. Note that these radiosondes are only shown for comparison and are not the same historical set of radiosondes used in calculating the CIMSS bias adjustment regression coefficients.

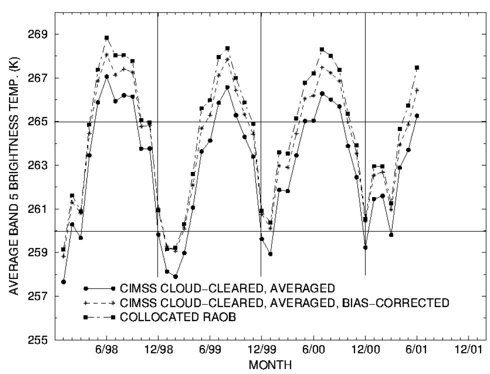

Fig. 4. CIMSS 12UTC GOES-8 monthly, averaged band 5 (13.4µm) retrieval brightness temperatures (measured and bias-corrected), along with average band 5 brightness temperatures computed for collocated radiosondes. Period is from January 1998 through June 2001.

The corresponding time series of OPS retrieval monthly-averaged band 5 brightness temperatures for the same period (not shown) is very similar, although the OPS average values are usually a fraction of a degree warmer than their CIMSS counterparts. Furthermore, and perhaps more significantly, the OPS bias-corrected brightness temperatures tend to be closer to the collocated radiosonde data than the CIMSS bias-corrected brightness temperatures. This may be a reflection of the more frequent updates of the OPS bias adjustment regression coefficients. The CIMSS bias adjustment regression coefficient database is likely in need of an update.

4. SUMMARY AND FUTURE WORK

This paper presents comparisons of satellite retrievals of temperature and moisture produced at CIMSS and NESDIS over the last several years, focussing on the derived product TPW. In terms of bulk statistics, both the CIMSS and NESDIS retrieved TPW exhibit a reduced SD when compared to its guess when compared to collocated radiosondes. In addition, the GOES-10 biases are usually smaller than GOES-8, and the GOES-10 SD values are always smaller than GOES-8.

Both the CIMSS and OPS GOES-8 and GOES-10 retrieval TPW biases tend to be more negative (retrieval drier than collocated radiosonde) in the warmer, more moist months. In terms of regional distributions of TPW bias, negative biases predominate for both the CIMSS and OPS retrievals, although pockets of positive biases also exist.

The radiance bias adjustment in Sounder band 5 (13.4µm) for both the CIMSS and OPS retrievals is such that the final bias-corrected brightness temperatures used in the physical retrieval algorithm agree more closely with nearby collocated radiosonde data than the uncorrected radiances.

By necessity due to space limitations, only retrieved TPW and band 5 bias adjustment data have been explicitly examined in this paper. At the conference, the comparisons will be expanded to include other retrieval parameters and Sounder bands. In particular, the radiance bias adjustment used at CIMSS and NESDIS will be examined more closely in an attempt to determine which is the better approach.

5. REFERENCES

Ma, X. L., T. J. Schmit, and W. L. Smith, 1999: A nonlinear physical retrieval algorithm—its application to the GOES-8/9 Sounder. *J. Appl. Meteor.*, **38**, 501-513.

Menzel, W. P., and J. F. W. Purdom, 1994: Introducing GOES-I: The first of a new generation of geostationary operational environmental satellites. *Bull. Amer. Meteor. Soc.*, **75**, 757-781.

Menzel, W. P., F. C. Holt, T. J. Schmit, R. M. Aune, A. J. Schreiner, G. S. Wade, and D. G. Gray, 1998: Application of GOES-8/9 soundings to weather forecasting and nowcasting. *Bull. Amer. Meteor. Soc.,* **79**, 2059-2077.

Schmit, T. J., 1996: Sounder bias correction of the east-west radiance gradient. *Proc. SPIE*, **2812**, Denver, CO, 630-637.

Weinreb, M. P., M. Jamieson, N. Fulton, Y. Chen, J. X. Johnson, J. Bremer, C. Smith, and J. Baucom, 1997: Operational calibration of Geostationary Operational Environmental Satellite-8 and –9 imagers and sounders. *Appl. Opt.*, **36**, 6895-6904.