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VALIDATION OF GOES AND MODIS ATMOSPHERIC PRODUCTS AND RADIANCES USING DEPARMENT OF ENERGY ATMOSPHERIC RADIATION (DOE ARM) MEASUREMENT DATA

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1. INTRODUCTION

The Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program (Stokes, 1994) has deployed a suite of ground-based in situ and remote sensing instrumentation to provide a long term (> 10 years) validation data set for General Circulation Models (GCM). The three DOE ARM measurement sites are named Southern Great Plains (SGP Oklahoma/Kansas region), North Slope of Alaska (NSA, near Barrow, Alaska), and Tropical Western Pacific (TWP). The main purpose of the ARM program is to improve knowledge of cloud radiative flux (shortwave and longwave) and to develop new GCM parameterizations to improve climate model forecasts. The ARM data sets have provided a unique high temporal resolution satellite validation source. The University of Wisconsin - Madison Space Science Engineering Center (SSEC) has a real-time direct broadcast downlink capability for the Geostationary Operational Environmental Satellites (GOES) and EOS-Terra data. The NOAA Cooperative Institute for Meteorological Satellite Studies (CIMSS) is producing atmospheric derived products from GOES and MODIS radiances, providing information about atmospheric stability, cloud properties, and moisture. ARM data sets are being used to validate GOES Total Precipitable Water (TPW), cloud tops, and atmospheric soundings derived from the GOES sounder. A best estimate temperature and moisture profile from the DOE ARM SGP site is being used to calculate radiance values for validation of GOES and MODIS radiance measurements. This paper will provide an overview of current DOE ARM measurements used for validation of these satellite products and recent conclusions.

2. GOES MOISTURE PRODUCT VALIDATION

The DOE ARM SGP site offers TPW measurements that allow for more precise validation of GOES retrievals than is possible with radiosondes. An operational microwave radiometer (MWR), located at the SGP central facility near Lamont, has demonstrated an accuracy of 0.7 mm under clear sky conditions (Liljegren 1995). All comparisons reported here are for clear sky cases. The MWR is tuned to the microwave emissions of the water vapor molecules in the atmosphere (Liljegren 1994) and measures TPW vapor every five minutes. The MWR measurements are completely independent of those from the GOES Sounder or radiosondes. These high temporal resolution MWR measurements enable validation of the GOES retrievals at times other than the conventional radiosonde launches (00 and 12 UTC). Of course, the MWR and GOES retrievals still differ in that one is a point measurement (although with an improved accuracy compared to radiosondes) and one a volumetric measurement.

TPW values computed from GOES-8 retrievals (Ma et al. 1999) and their corresponding first guess profiles were compared to the MWR TPW for a 29-day period between 20 March – 17 April 1998. The temporal resolution for GOES-8 was routine hourly profiling. Figure 1 shows a one-day comparison of TPW on 12 April 1998 between the MWR and GOES-8. While the first guess (diamonds), which was interpolated from 6-hourly forecasts, is relatively flat throughout the period, the GOES retrieval algorithm (pluses) produces nearly the same water vapor tendency patterns as measured by the MWR (dashed line). The satellite retrieval uses a 3 x 3 FOV matrix (equating to a 36 km x 45 km box at this geographic location), representing a volumetric profile over a larger horizontal area than the MWR (which represents the atmosphere directly above the instrument). Smooth temporal changes are generated by the GOES physical retrieval algorithm, even when the first guess experiences a discontinuity when switched from using forecasts from the 00 UTC to the 12 UTC model initialization times (e.g. near 18 UTC). These discontinuities could be minimized if the forecasts from the 06 UTC and 18 UTC initialization times were also used to build the first guess profiles for the GOES retrievals. The GOES retrievals follow the water vapor fluctuations between a local minimum of approximately 13 mm at 1130 UTC and a maximum of approximately 24 mm at 14 UTC; the temporally and spatially coarse

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radiosonde network did not capture these changes. Overall, GOES demonstrates skill in resolving the mesoscale water vapor fluctuations on this day.

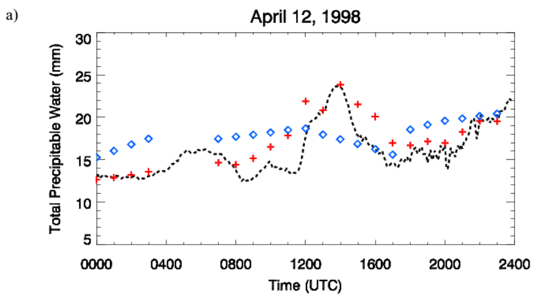

Figure 1: Microwave radiometer (dashed line), Eta model forecast (diamond symbols), and GOES-8 physical retrieval (plus symbols) total precipitable water vapor comparisons near Lamont, Oklahoma on 12 April 1998.

Figure 2 shows the improved agreement of the GOES physical retrieval algorithm (stars) versus the first guess (diamonds) when compared to the MWR measurements during the period 20 March to 17 April 1998. These data were derived by comparing all possible matches between GOES-8 retrievals and the MWR instrument. For the 364 matched values of MWR and GOES-8 shown in Fig. 2, the physical retrieval improves the first guess of TPW RMS from 2.21 to 1.80 mm and the bias from 0.83 to 0.40 mm. Even at greater TPW values, the GOES retrieval values compared better with microwave radiometer values (perfect agreement indicated by the diagonal line).

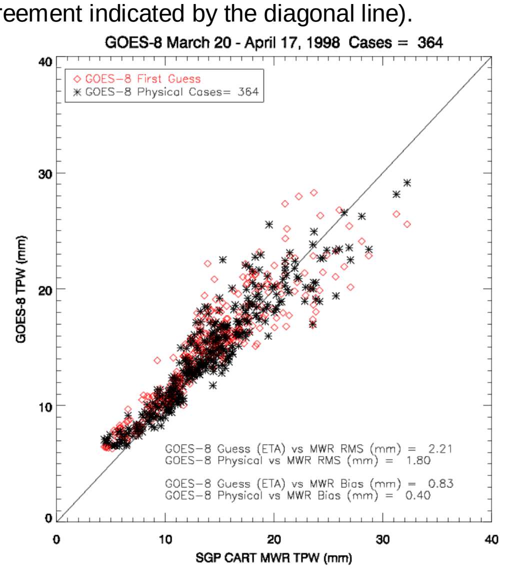

Figure 2: A scatter plot comparing MWR total water vapor values to the Eta model forecast (diamond symbols) and the GOES-8 physical retrieval (star symbols) values. RMS and bias for all matches are quantified in the lower right hand corner.

The DOE ARM microwave radiometer data has provided a valuable stable validation source for space-borne total precipitable water measurements at high temporal resolution. These data are also used to derive the post-launch tests for GOES (Daniels and Schmit 2001). Real-time TPW validation has been implemented at SSEC CIMSS UW-Madison to provide near instantaneous meteorological satellite product evaluation. More information about the evaluation of GOES TPW can be obtained in Schmit et al 2001.

3. GOES CLOUD TOP VALIDATION

A consensus cloud boundary product has been developed for the DOE ARM sites by using combined cloud information from the Microwave Millimeter Cloud Radar (MMCR) and MicroPulse Lidar (MPL). This product was used to validate hourly GOES sounder derived cloud top pressures for March 2000 at the central facility DOE ARM SGP near Lamont, Oklahoma. The DOE ARM cloud boundary data has a time resolution of 10 seconds and is determined over a narrow column of atmosphere over Lamont, Oklahoma. The GOES cloud product is derived from 3x3 FOV and provides an average cloud top pressure as well as minimum and maximum pressures. The technique for determining the GOES cloud top pressure is described in Schreiner et al. 2001. Due to the high temporal and spatial resolution of the DOE ARM cloud boundary product, five minute binning of this product on either side of an hourly GOES determined cloud top was done to minimize resolution discrepancies between the ground-based and space-borne cloud top determination. To simplify the comparison, multiple layered cloud scenes where removed from the samples. This was determined in the GOES 3x3 FOV by analysis of the minimum and maximum cloud top pressure altitude. Cloud top altitude differences of 2 km or less were used within the analysis generally providing uniform cloud top cases.

After accounting for spatial and temporal resolution differences and filtering multiple layer cloud cases, 73 matches between hourly GOES and 10 second MMCR/MPL cloud products were determined for March 2000 near Lamont, Oklahoma (Figure 3). A high correlation of 0.93 with an RMS of 930 meters was calculated. The two outliers in the figure are probably due GOES inability to detect very thin cirrus clouds with low emissivity/optical depth. This study will be expanded to use data for all months in the year 2000 to provide a more robust comparison and provide insight for GOES cloud top pressure altitude algorithm improvement. For more information on this study, view Hawkinson et al. 2001 (presented in these proceedings).

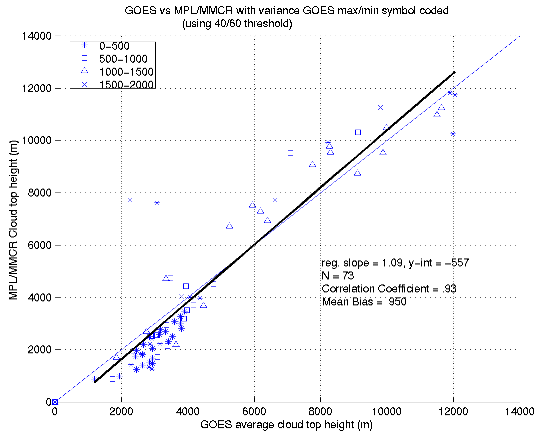

Figure 3: A scatter plot comparing DOE ARM ground-based MPL/MMCR and space-borne GOES derived cloud top altitude after resolution binning and multiple level clouds are removed. A correlation coefficient of 0.93 and a mean bias of 950 m was determined.

4. CONCLUSIONS

DOE ARM data have become an important validation sources for geostationary and polar orbiting satellite platform sounder instrumentation. GOES TPW and cloud top products are being extensively evaluated with the data. GOES cloud top estimates have shown a correlation of 0.93 and RMS differences of approximately one kilometer. The GOES moisture retrieval algorithm improves the precipitable water values from the ETA model first guess by 0.4 millimeters in both an RMS and mean statistical sense as compared the a DOE ARM microwave radiometer. A best estimate product for temperature and moisture derived from DOE SGP site Raman Lidar, AERI, MWR, and radiosonde information is currently providing a way to evaluate EOS Terra (and soon EOS Aqua) overpass radiance calibration (see Wetzel et al. 2001 in these conference proceedings). The DOE ARM NSA and TWP sites will be extensively used to evaluate cloud and thermodynamic retrievals for EOS AIRS and MODIS polar orbiting overpasses in the near future.

5. ACKNOWLEDGEMENTS

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