2.7 VALIDATION OF A NEURAL NETWORK BASED MODIS GLOBAL CLOUD MASK USING GROUND-BASED INSTRUMENTS

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1. INTRODUCTION

Validation is an important stage in the development and evaluation of satellite derived cloud masking and classification algorithms. Ground-based instruments provide an independent means of validating satellite based cloud masks.

2. MODIS CLOUD MASK

As part of the Clouds and the Earth's Radiant Energy Systems program (CERES), a polar and global classifier and cloud mask is being developed using MODIS data. The supervised classifier is based upon a back-propagation neural network (Berendes et al., 1999). Training samples are selected by an expert using the Interactive Visualizer and Image Classifier for Satellites (IVICS) (Berendes, et al, 2001). The neural network is then trained using the selected samples and a cloud mask is created. IVICS is then used to provide a subjective evaluation of the accuracy of the cloud mask and help refine the classifier.

3. CLOUD VALIDATION DATABASE AND RETREIVAL SYSTEM

To obtain an objective evaluation of cloud mask accuracy, an independent data set is needed. The Cloud Validation Database and Retrieval System (CVDRS) is a set of independent ground based data and software programs which provide time-matched retrieval and analysis of cloud cover at specified site locations. These independent estimates of cloud cover are used to objectively validate the satellite classifier derived cloud mask.

Presently, the database is populated with ceilometer, lidar, radar, whole-sky imager, and other cloud cover instrument data. The CVDRS is expandable to allow additional validation sites and instruments.

Radiometers are used in conjunction with the other data to provide optical depth and aerosol information. Work is also underway to derive a more direct measure of cloud cover using radiometers.

The Atmospheric Radiation Measurement Program (ARM) sites compose the initial set of validation sites. The North Slope of Alaska (NSA) ARM site is of particular interest since it is one of the few polar sites. Vaisalla ceilometer, micropulse lidar and whole-sky imager data is available at most of the ARM sites. Active Remote Sensing of Clouds (ARSCL) (Clothiaux, et al., 2000) is a value added product which combines ceilometer, lidar and radar. ARSCL contains many derived cloud properties including several cloud base heights from which cloud cover is computed for overpass time periods.

Ceilometer and total-sky imager data acquired on the Explorer of the Seas cruise ship is integrated into the database. The ship was travelling in the western tropical and subtropical Atlantic Ocean. The goal is to expand the database to include data from many sites all over the world.

Currently, the database consists only of data from 2000 and 2001. Due to instrument downtime and data processing delays, it is difficult to get continuous data for all of the instruments. The CVDRS is designed to handle data gaps and will simply find as many matching instruments for a query as available.

The CVDRS is designed to be user friendly and flexible. Any of the search and analysis parameters of the CVDRS may be customized by the user. The output is in a standard netCDF format. An interface to the CVDRS has been successfully integrated into IVICS allowing interactive validation of satellite images.

4. PRELIMARY RESULTS

Before we can use various ground based instrument data for validation of the cloud mask, we must first check for consistency between the instruments. Figure 1 compares micropulse lidar with Vaisalla ceilometer at the Barrow, AK ARM site (NSA). Figure 1 shows that micropulse lidar (MPL) detects more clouds than the Vaisalla Ceilometer. The "X" symbols indicate high clouds (> 6000 m). Some of those clouds are above the 7.5 Km maximum vertical range of the Vaisalla ceilometer and are therefore undetected. They are, however, detected by the micropulse lidar and show up as points along the x - axis.

As seen in the histogram in Figure 1, most of the site matches have very heavy cloud cover (90 – 100%). In general, most of the instruments agree when there is heavy cloud cover.

More extensive inter-comparisons must be performed to determine the conditions under which each instrument provides reliable estimates of cloud cover.

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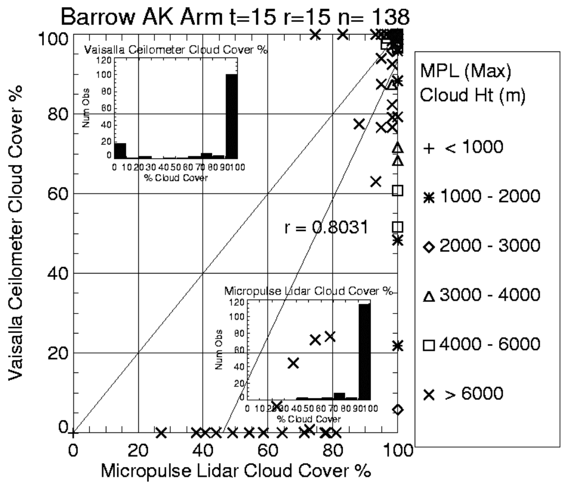

Figure 1. Scatter plot of micropulse lidar cloud cover vs. Vaisalla Ceilometer cloud cover for a time interval of +/- 15 minutes of satellite overpass of the Barrow ARM site. Point symbols indicate the maximum micropulse lidar cloud height within the time window. A linear regression line is drawn and labeled with the correlation coefficient (r = 0.8031). Histograms are inset for each of the axes.

Daytime MODIS data was extracted for the Barrow, Alaska ARM site and a cloud mask was created from the classifier results. Then the cloud cover was computed within a radius of 15 Km of the ARM site. Figure 2 shows a comparison between the satellite classifier results and the MPL. The correlation is poor (r = .5016) and, in general, the MPL finds much more cloud than the satellite classifier. This could be due to the MPL detecting more high thin cirrus or optically thick aerosols.

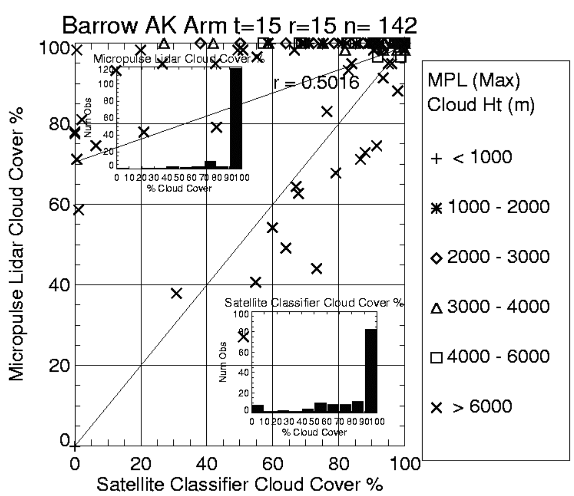

Figure 2. Scatter plot of MODIS satellite classifier cloud cover vs. micropulse lidar cloud cover with a time interval of +/- 15 minutes of satellite overpass and a radius of 15 Km around the Barrow ARM site.

Since the MPL and Vaisalla ceilometer detect different cloud amounts, it is apparent that one instrument alone may not provide a "validation" for the satellite mask. Composite value-added products such as the ARSCL data may provide a better estimate of "ground truth". Figure 3 shows a plot of the satellite classifier and the ARSCL Best Estimate composite. The correlation is better than MPL alone (r = 0.5965), but the ARSCL also detects more clouds than the satellite classifier.

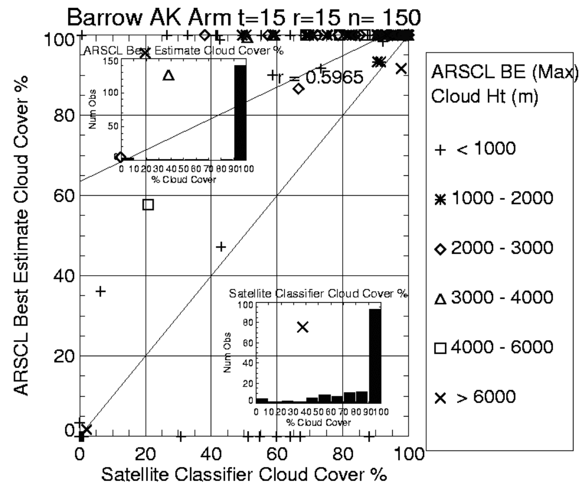

Figure 3. Scatter plot of MODIS satellite classifier cloud cover vs. ARSCL Best Estimate cloud cover with a time interval of +/- 15 minutes of satellite overpass and a radius of 15 Km around the Barrow ARM site.

Another instrument we use is the Millimeter Cloud Radar (MMCR). Figure 4 shows a comparison of the satellite classifier with the MMCR for the Barrow, AK, ARM site.

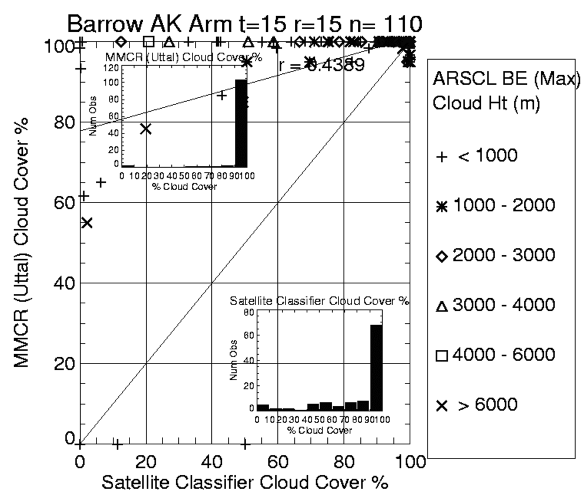

Figure 4. Scatter plot of MODIS satellite classifier cloud cover vs. millimeter cloud radar (MMCR) cloud cover with a time interval of +/- 15 minutes of satellite overpass and a radius of 15 Km around the Barrow ARM Site.

Again we see that the ground based instrument detects more cloud cover than the satellite method. The

MMCR method also detects more clouds than the other ground-based instruments.

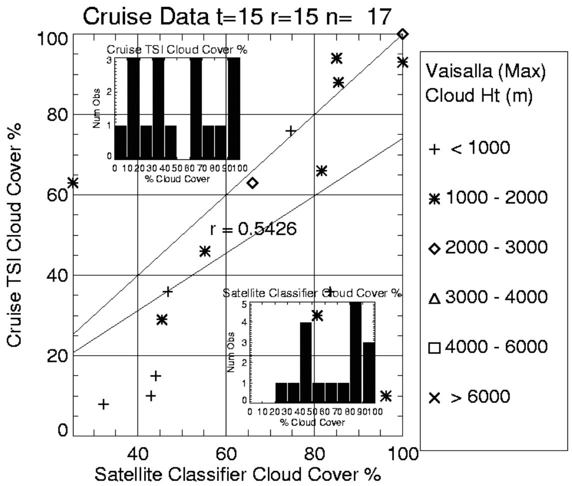

Figure 5. Scatter plot of MODIS satellite classifier cloud cover vs. Total sky imager cloud cover with a time interval of +/- 15 minutes of satellite overpass and a radius of 15 Km around the Explorer of the Seas cruise ship.

To illustrate the flexibility of the CVDRS, Figure 5 shows a comparison of the satellite cloud mask with Total - Sky Imager data acquired on a moving cruise ship. We currently have cruise ship data for the first six months of 2001.

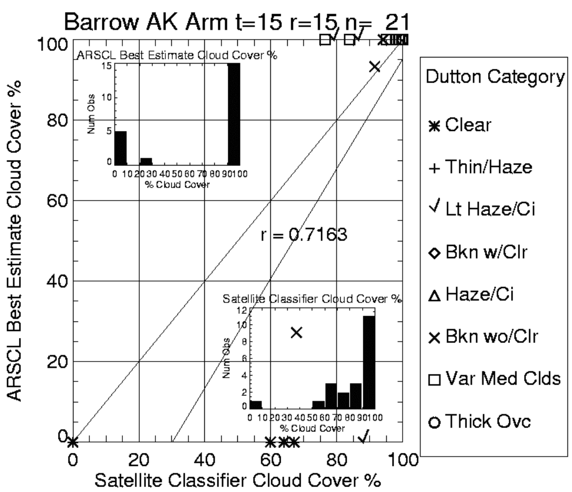

Figure 6. Scatter plot of MODIS satellite classifier cloud cover vs. ARSCL best estimate cloud cover with a time interval of +/- 15 minutes of satellite overpass and a radius of 15 Km around the Barrow ARM Site. Plot symbols indicate cloud category derived by Dutton from radiometer data.

Radiometer data may provide an independent means for determining the cloud detection sensitivity of the various instruments and the satellite cloud mask. Figure 6 shows a comparison of the ARSCL best estimate with the Satellite classifier. The radiometer data has been analyzed using a time window of +/- 20 minutes. Categories have been defined corresponding to the presence of clouds and aerosols detected by the radiometer. Notice that there are points where the satellite classifier is finding 60 – 70% cloud cover while the ARSCL best estimate is finding 0%. The Dutton cloud category is "Clear" for those points indicating a possible error in the satellite mask.

5. CONCLUSIONS

The CVDRS is user-friendly and expandable. It extracts cloud cover estimates from multiple ground based instruments.

Each of the different instruments and algorithms has their own unique cloud detection capabilities. Using a combination of the various instruments may be necessary to provide a reasonable estimate of the actual cloud cover. We must understand the limitations and differences between the various instruments in order to use them for validation. More extensive inter-comparisons are being performed to determine which instruments provide the best estimates of cloud cover. IVICS will be used to look at discrepancies and try to understand their causes.

The predominant background surface for Barrow is snow and ice with high surface albedo. We suspect that the satellite classifier is under-detecting cloud (especially thin clouds and cirrus) over snow and ice which may be the cause of the bias we see in the figures. We will be examining data from the ARM Southern Great Plains (SGP) site and other locations to provide a better assessment of the performance of the algorithms. More studies are needed to assess the time window and site radius parameters.

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6. REFERENCES

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