MODIS Semi-annual Report (July 2002 – December 2002)

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(This reports covers the MODIS **cirrus characterization and correction** algorithm and the MODIS **near-IR water vapor algorithm**)

Main topics addressed in this time period:

1. **MODIS near-IR water vapor algorithm**:

During this reporting period, our main activities on MODIS near-IR water vapor algorithm include: (a) evaluation of AQUA MODIS L1B images and L2 near-IR water vapor images, (b) additional validation of MODIS near-IR water vapor retrievals using ground-based upward-looking microwave radiometer measurements, and (c) writing a paper on MODIS near-IR water vapor algorithm and showing sample results. We didn't make any modifications and upgrades to the near-IR water vapor codes. The algorithm is quite stable now.

We made extensive analysis of L1B AQUA MODIS images for 5 near-IR channels centered near 0.865, 0.905, 0.935, 0.94, and 1.24 micron. These channels are used in the near-IR water vapor algorithm. We also studied L2 MOD05 near-IR water vapor images over different geographical regions. We feel that the quality of AQUA MODIS data for these channels is very good. The water vapor values retrieved from these images are also expected. No major anomaly is found. We provided a few sample AQUA near-IR water vapor images to NASA managers to be used in their presentations. In Figure 1 we show an example of AQUA MODIS near-IR water vapor image (the right panel) over Spain and Morocco (the left panel). The water vapor values near the land-water boundary areas are significantly larger than those over desert areas. In Figure 2 we show another example of water vapor retrievals over the northern part of Africa Continent. Nile Delta is located in the middle right portion of the scene. The coast of Libya is also seen obviously in the image. The water vapor values over land areas close to the Mediterranean Sea are significantly greater than those over the interior desert areas.

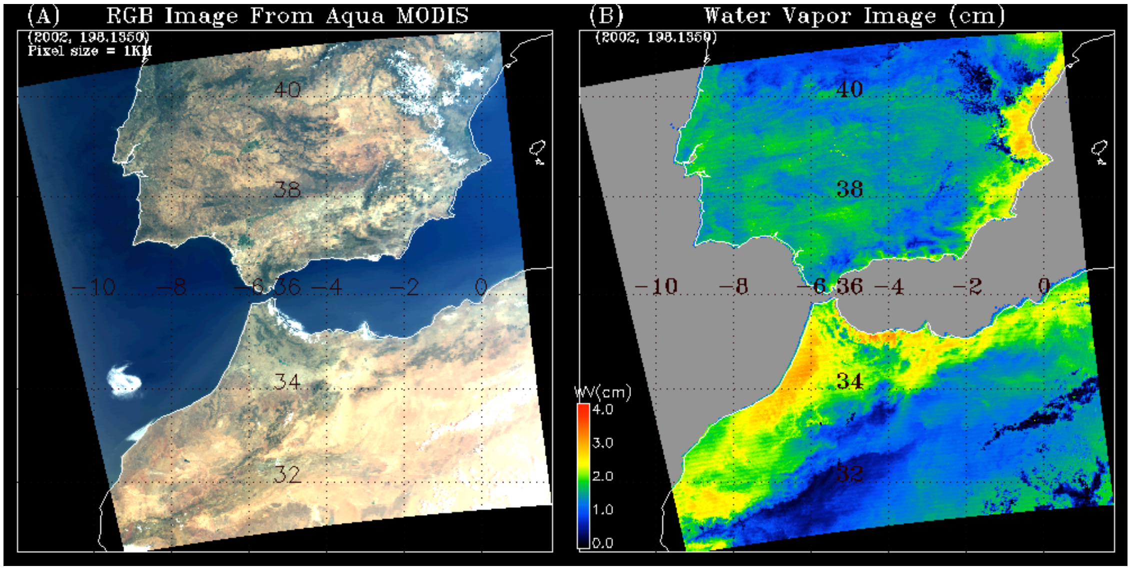

Fig. 1. An RGB image and a near-IR water vapor image obtained from AQUA MODIS measurements over Spain and Morocco.

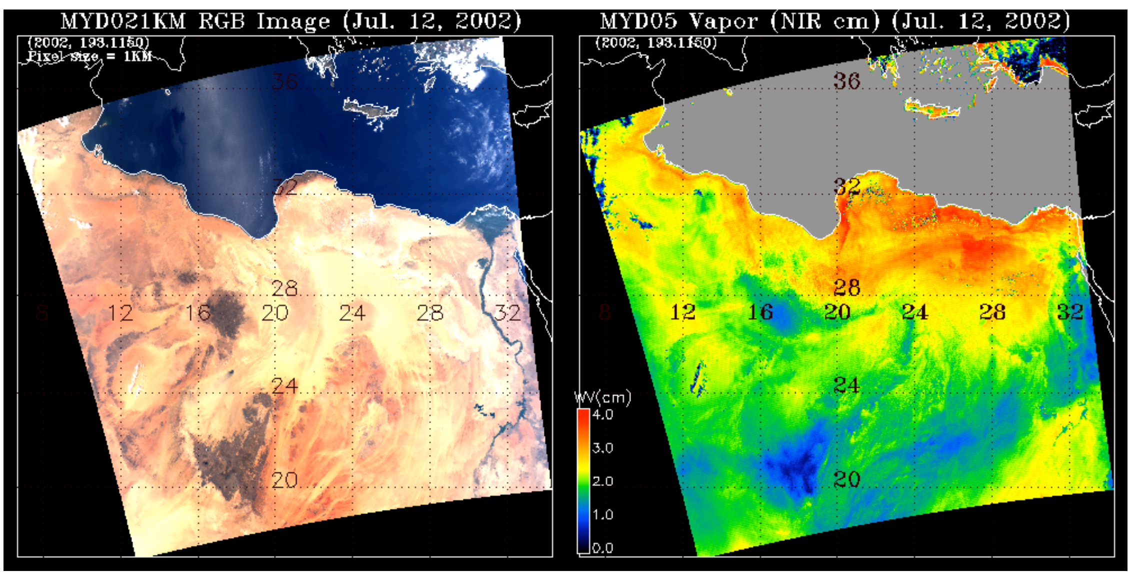

Fig. 2. An RGB image and a near-IR water vapor image obtained from AQUA MODIS measurements over northern part of the Africa Continent.

We made additional efforts in validation of MODIS near-IR water vapor retrievals using ground-based upward looking microwave radiometer data. The radiometer data was collected by Dr. Si-Chee Tsay's research group during a field experiment in Miami, Florida in July, 2002. There were only a few clear days for the entire month of July. The airmass changed rapidly over Miami and nearby areas. These factors make it difficult to compare MODIS water vapor values and microwave radiometer water vapor values. It is difficult to reach any firm conclusions based on such comparisons.

A manuscript describing the MODIS near-IR water vapor algorithm and presenting sample results was written (based on modifications to the MOD05 ATBD) and was submitted to Journal of Geophysics Research – Atmosphere in October of 2002.

2. **MODIS cirrus reflectance algorithms**:

During this time period, we made minor upgrades to the MODIS cirrus reflectance algorithm. Specifically, we changed the procedures for assigning QA parameters. After the upgrades, less pixels are assigned as "cirrus" pixels, and cirrus fraction is decreased.

We evaluated the performance of the AQUA MODIS 1.38-micron channel. The cross-talking effect is decreased significantly in comparison with the Terra MODIS, but can still be seen. The 10 detectors do not have equal responses. Bright horizontal lines are seen. Because the MODIS data we studied were generated using the at-launch version of lookup tables, we cannot reach firm conclusions about the performance of the 1.38-micron channel of the AQUA MODIS instrument.

In August of 2002, we revised the manuscript entitled "detection of high clouds in polar regions during the daytime using the MODIS 1.375-micron channel". The manuscript has been accepted for publication by IEEE and will be published in the future AQUA Special Issue of IEEE Trans. Geosci. Remote Sensing. Two versions of the manuscript similar to the one accepted by IEEE were previously rejected by two journals - once by JGR-Atmosphere and once by Journal of Applied Meteorology (JAM). The reviewers for both journals felt that something was seriously wrong with our manuscripts. They were comfortable with the traditional radiance or brightness temperature thresholding techniques for cloud detections. They could not understand the fact that, in the case of 1.38-micron image, the clear background pixels are totally dark, and it is not necessary to select a threshold to eliminate the background effects for cloud detections using the 1.38-micron channel. It was a bit ironic that we had to rely on the special IEEE AQUA issue in order for the manuscript to successfully go through the reviewing process. The guest editor(s) of AQUA issue most likely sent our manuscript to reviewers who understood the nature of the 1.38-micron channel.

Previously, researchers from University of Wisconsin and Raytheon raised doubt about the ability of detecting polar clouds using the 1.38-micron MODIS channel because of concerns on the dry atmosphere and surface reflections at 1.38 micron in polar regions. After the acceptance of our polar cloud detection manuscript by IEEE, we did additional systematic studies of MODIS images for a visible channel, 1.38-micron channel, and the 11 micron channel over both the Arctic and Antarctic regions. Figure 3 shows an example of comparisons for a scene over the Arctic region. Surface features seen in the 0.66-micron and 11-micron image are not seen in the 1.38-micron image at all. The 1.38-micron channel image detects quite well all the cloud features in the scene.

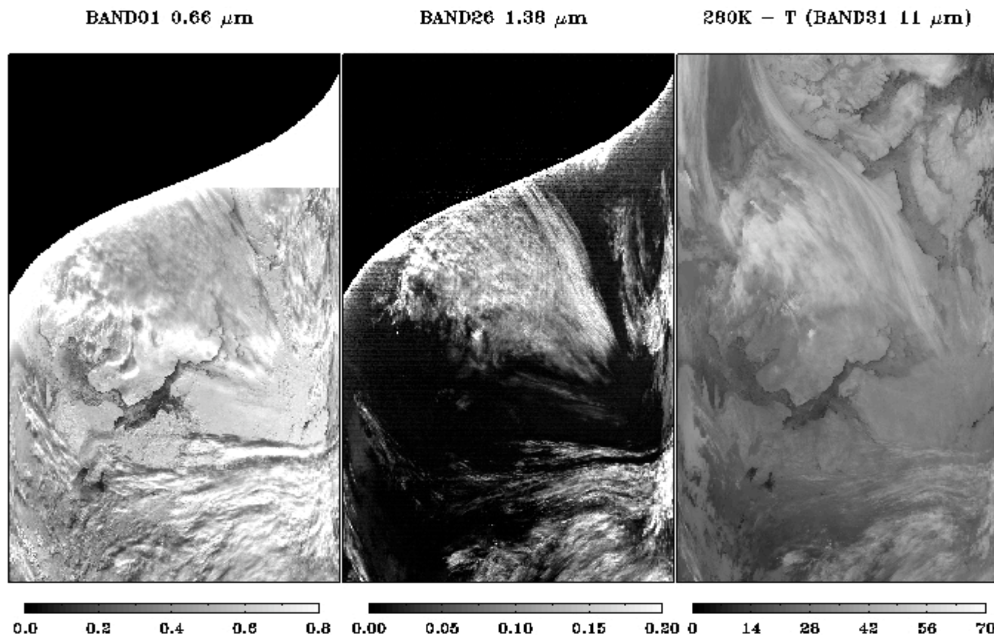

Fig. 3. Comparison of images for the 0.66-, 1.38-, and 11-micron MODIS channels for a scene over the Arctic region.

Figure 4 shows an example of image comparisons for a scene over the Antarctic region. The long land-ocean boundary lines are seen in the left part of the 0.66-micron and 11-micron images. These lines are not seen in the 1.38-micron image. Cloud features in the bottom half of the 1.38-micron channel image are seen quite well. These comparisons further demonstrate the effectiveness of polar cloud detection using the 1.38-micron MODIS channel during the daytime. The surface reflection at 1.38 micron in polar regions is most likely very small due to large ice particle sizes (several hundred micron) of snow and ice-covered surfaces and very strong absorption at 1.38 micron by these large ice particles. The ice particles in polar clouds are typically small (on the order of 10 micron). The absorption effects by these particles at 1.38 micron are very small. These particles are efficient scatters of solar radiation, and allow the detection of polar clouds with the 1.38-micron channel**.**

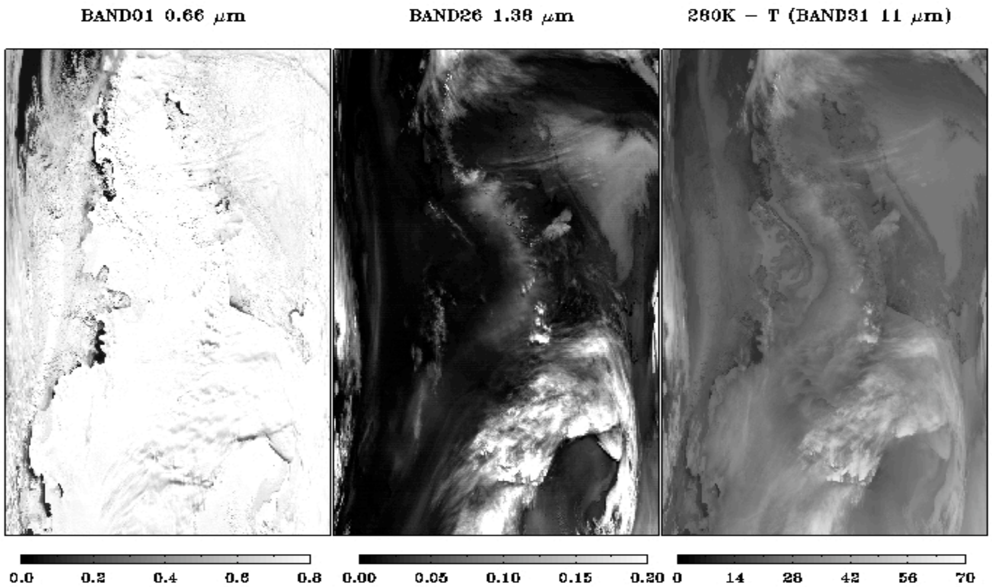

Fig. 4. Comparison of images for the 0.66-, 1.38-, and 11-micron MODIS channels for a scene over the Antarctic region.

Working closely with Dr. Kaufman's research group at NASA Goddard, an improved cirrus screening method using the 1.24-μm/1.38-μm channel ratio for the MODIS aerosol retrieving algorithm has been developed and implemented to the aerosol algorithm. In July of 2002, we revised a manuscript that addressed the cirrus contamination problems in earlier versions of MODIS aerosol algorithms. The manuscript was published by GRL in December of 2002.

Although the aerosol optical depths and particle size distributions retrieved with the earlier versions of MODIS aerosol algorithms are known to have cirrus-contamination problems, these aerosol images are still being widely publicized. We feel that the integrity of aerosol science is not well maintained. For example, the monthly-mean aerosol images for September 2000 have been published in Kaufman et al.'s 2002 nature inside review paper, in Remer et al.'s 2002 aerosol validation GRL paper, and in the recent NASA MODIS brochure (NP-2002-1-423-GSFC). Through careful examinations of MODIS L1B and Level

2 MOD04 and MOD05 data for this month, I feel that the cloud contamination problems in the monthly-mean aerosol images are quite significant. In Fig. 1b of Kaufman et al.'s nature paper, three rectangular boxes were drawn. Box A covered areas west to the coast of northern Africa in the Atlantic Ocean. The red and yellow features in this box gave readers an impression that huge amount of dusts over this area were present for the entire month of September of 2000. By examining all the daily visible channel images over this area and posted on the MODIS Atmosphere Group's web page, I can see only one nice case (September 26) of dusts covering a large area in the Atlantic Ocean. Dusts were not present for the 1st half of September. The rest of cases were always dusts mixed with clouds. Since the aerosol retrieving algorithm treated thin cirrus clouds as dusts, the dust aerosol optical depths over the Box A covered areas were greatly exaggerated. Box C covered areas over the Bay of Bengal and Arabian Sea. The claimed desert dusts over these areas by Kaufman et al. are also most likely due to thin cirrus contaminations. Below we show examples of obvious cloud contaminations in MOD04 optical depth retrievals.

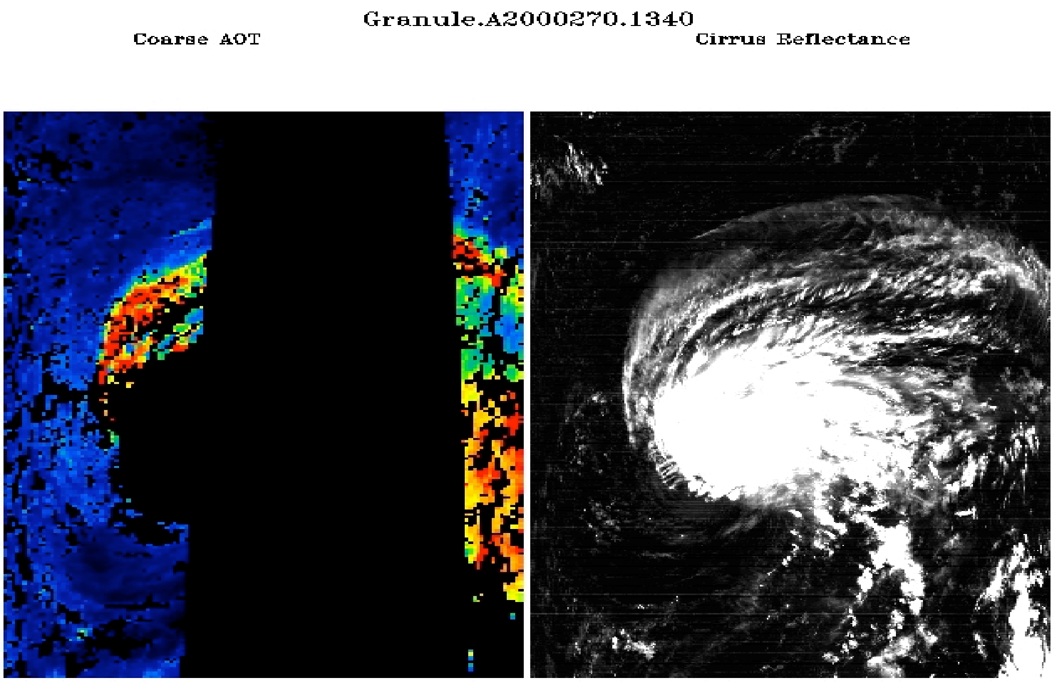

Fig. 5. Aerosol optical depth (coarse particle mode) (left panel) and cirrus reflectance images (right panel) for a MODIS scene over the Atlantic Ocean.

The left panel of Figure 5 shows an optical depth image over the Atlantic Ocean, and the right panel shows the 1.38-micron channel reflectance image over the same areas. Thin cirrus clouds in the outer edges of a huge cloud system were treated as dust particles. Figure 6 shows a similar comparison but for a scene over the Arabian Sea. The aerosol optical depths over the bottom half of the scene are contaminated by thin cirrus clouds.

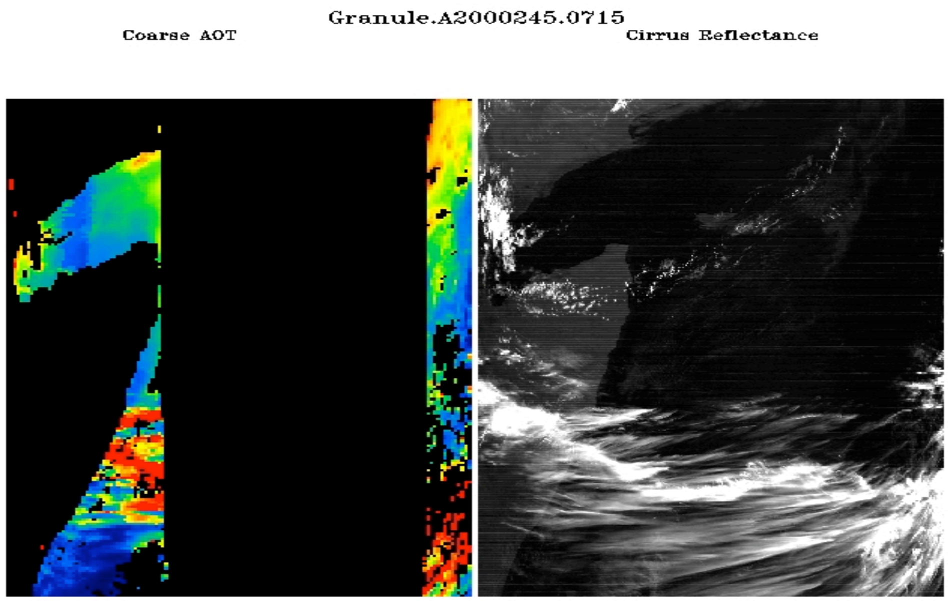

Fig. 6. Aerosol optical depth (coarse particle mode) (left panel) and cirrus reflectance images (right panel) for a MODIS scene over the Arabian Sea.

After the re-processing of MODIS data with the Collection 4 softwares, the cirrus contamination problems associated with the MODIS aerosol retrievals are expected to decrease significantly. However, this does not alter the facts that incorrect MODIS aerosol images have already been published in major scientific journals, such as Nature, and Science (in a paper by Ramanathan et al., 2002).

It should be pointed out that the cirrus contamination problem is not unique to the MODIS aerosol products. The aerosol products derived from AVHRR and SeaWiFS data are also seriously contaminated by thin cirrus clouds. The SeaWiFS aeroaol optical depth images have recently been used by NASA Goddard scientists for the study of aerosol radiative forcing, and incorrect conclusions have been reached.

3. **Seasonal and Annual Variations of Water Vapor and Cirrus Clouds**:

During this time period, we continued the study of seasonal and annual variations of water vapor and cirrus clouds using the monthly-mean Level-3 global data products. We tried to see differences between a normal year and an

El Nino year. Below we show examples of large differences between the two years over two geographical regions.

In Figure 7 we show a cirrus reflectance difference image between January 2002 and January 2001 over Australia and Indonesia. The color coding is made in such a way that blue corresponds to a reflectance difference of –0.2, and red +0.2. From this image, we see that in January 2002, the reflectivity of cirrus clouds over Indonesia decreased while that over areas east of Indonesia increased in comparison with the January 2001 cirrus reflectances. This is due to the eastward movement of warm pool during the El Nino year.

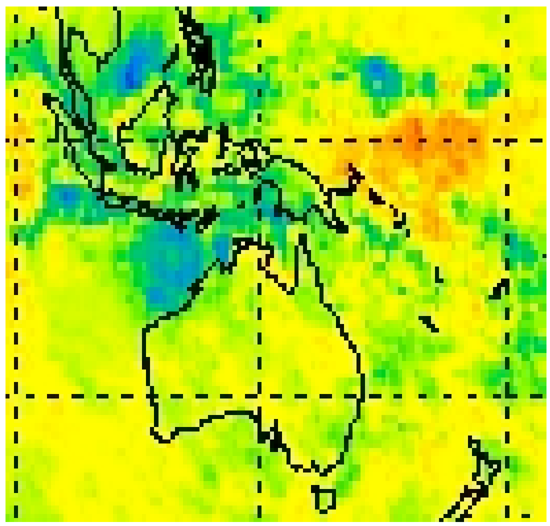

Fig. 7. A cirrus reflectance difference image between January 2002 and January 2001 over Australia and Indonesia.

In Figure 8 we show a column water vapor difference image between July 2002 and July 2001 over the India Continent and the Bay of Bengal. The color coding is made in such a way that blue corresponds to a water vapor difference of –4.0 cm, and red +4.0 cm. From this image, we see that in July 2002, the water vapor amount over the northwestern part of India decreased significantly in comparison with the same month in 2001. The opposite is true for areas over the Bay of Bengal.

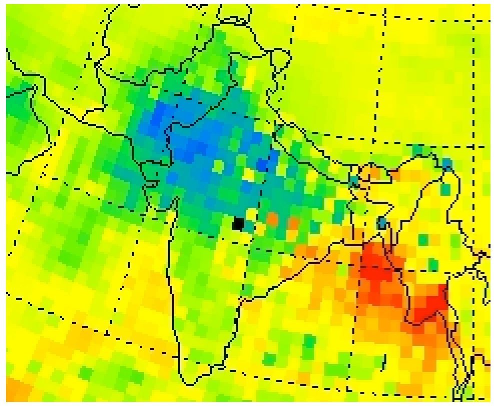

Fig. 8. A column water vapor difference image between July 2002 and July 2001 over the India Continent and the Bay of Bengal.

4 **Publications**:

Gao, B.-C., and Y. J. Kaufman, Water vapor retrievals from images of MODIS near-IR channels, submitted to JGR-Atmosphere in October 2002.

Li, R.-R., Y. J. Kaufman, B.-C. Gao, and C. O. Davis, Remote sensing of suspended sediments and shallow coastal waters, Accepted for publication by IEEE Trans. Geosci. Remote Sensing in November 2002.

Gao, B.-C., Y. J. Kaufman, D. Tanre, and R.-R. Li, Distinguishing tropospheric aerosols from thin cirrus clouds for improved aerosol retrievals using the ratio of 1.38-micron and 1.24-micron channels, Geophys. Res. Lett., 29, 1890, 2002.

Gao, B.-C., P. Yang, R.-R. Li, S. K. Park, and W. J. Wiscombe, Detection of high clouds in polar regions during the daytime using the MODIS 1.375-micron channel, accepted for publication by IEEE Transa. Geosci. Remote Sensing in August 2002.

King, M. D., W. P. Menzel, Y. J. Kaufman, D. Tanre, B.-C. Gao, S. Platnick, S. A. Ackerman, L. A. Remer, R. Pincus, and P. A. Hubanks, Cloud and aerosol properties, precipitable water, and profiles of temperature and water vapor from MODIS, accepted for publication by IEEE Trans. Geosci. Remote Sensing in Nov. 2002.

Gao, B.-C., P. Yang, W. Han, R.-R. Li, and W. J. Wiscombe, An algorithm using visible and 1.38-micron channels to retrieve cirrus cloud reflectances from aircraft and satellite data, IEEE Trans. Geosci. Remote Sensing, 40, 1659 – 1668, 2002.

Yang, P., B.-C. Gao, W. J. Wiscombe, M. I. Mishchenko, S. Platnick, H.-L. Huang, B. A. Baum, Y. X. Hu, D. Winker, S.-C. Tsay, and S. K. Park, Inherent and apparent scattering properties of coated or uncoated spheres embedded in an absorbing host medium, Appl. Opt., 41, 2740 – 2759, 2002.