MODIS Semi-annual Report (July 1997 - December 1997)

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

Main topics addressed in this time period:

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

Science algorithm: Our V1 MODIS near-IR water vapor science algorithm assumed a two-way transmission model during the derivation of water vapor values from MODIS data. However, under hazy conditions and over dark surfaces, correction of aerosol effects is needed. A module using aerosol optical depths from Yoram Kaufman's MOD04 algorithm has been developed by Gao and Han for correction of aerosol effects in our retrieved water vapor values. Han and Chu have made major efforts to speed up the CPU time for making the corrections for a complete MODIS data cube. Originally, it takes more than 2 hours to make corrections for one MODIS cube. Straight forward searching of 6-dimensional tables can be quite time consuming when processing all pixels in a MODIS scene. Now the time has been reduced to a few minutes per scene.

Metadata: The level 2 and level 3 metadata issues for the near-IR water vapor algorithm were mainly handled by Allen Chu, who needed to constantly chase the ever-evolving standards. Unhappiness and frustrations occurred during the handling of the metadata issues.

Code integration: The reader for the V2 near-IR water vapor algorithm was obtained through modifications to the V1 reader by Chu. He also handled the code integration and most of the delivery related issues. The combined V2 near-IR water vapor and aerosol algorithm was delivered to the MODIS Project in mid-November of 1997.

2. **MODIS thin cirrus and contrail algorithm**:

Science algorithm: The science algorithm includes two parts: thin cirrus reflectance and contrail detection.

a) Thin cirrus reflectance: The 1.375-µm MODIS channel is very sensitive in detecting thin cirrus clouds. The channel is also affected by absorption from water vapor above and within cirrus clouds. In order to use this channel for quantitative removal of thin cirrus effects, the water vapor absorption effects must be estimated. The magnitude of the absorption depends on the amount of water vapor, the solar and view zenith angles. A lookup table has been produced for correction of angular dependencies of water vapor absorption. The at-launch version of the algorithm is simple. We assume that the two-way water vapor transmittances of the 1.375-µm channel in the vertical direction is about 0.7, then we take account for solar and view angle dependencies. The cirrus reflectance in the 0.4-1.0 µm region is equal to the apparent reflectance of 1.375-µm channel divided by the water vapor transmittance. The cirrus reflectance estimated this way is likely to be 60% to 90% of the true cirrus reflectance in the visible. If the MODIS ocean color algorithm subtracts out our estimated cirrus reflectances from apparent reflectances of ocean color channels, we expect that many pixels covered by thin cirrus clouds can be used in ocean color retrievals. We intentionally not to over estimate the thin cirrus reflectances. If we under estimate the cirrus effects, ocean color algorithm can correct the remaining thin cirrus effects as white aerosols. If we over-estimated the cirrus reflectances, negative water leaving radiances in the visible would occur. Our cirrus reflectance product can also be used to improve the MODIS land products, such as vegetation indices.

b) Contrail detection: Aircraft contrails resulted from commercial aircraft emissions may have radiative effects on the Earth's radiation budget (see an article entitled "aircraft contrails reduce solar irradiance" published on the October 14, 1997 issue of AGU's EOS magazine). Detection of contrails from AVHRR and GOES data are practically difficult. Images of the 1.375-µm MODIS channel, which usually do not have surface and low level cloud contamination, will be very useful for contrail detection during the day time. Bill Ridgway has made additional progress with the contrail detection algorithm. He studied contrail detection algorithms of Ron Welch and a German group, and came up with a slightly different way to form a "gradient-based" image. From this image, contrails can be detected more easily than from the original radiance image.

Development effort has been focused on three objectives: (i) delivery of a working version of the contrail detection code, (ii) further testing of the algorithm on proxy images, and (iii) algorithm refinements based on theoretical insights and trials on test images.

A functioning algorithm for contrail detection, written in FORTRAN 90, was ready for code integration in November. The algorithm produces a "contrail mask" image from the 1.38 micron brightness image. In order to limit code memory requirements, each input scene (with size up to 2000x3000 pixels) is split into four equal sub-scenes before processing. The resultant contrail mask is reconstructed from the corresponding sub-scenes.

Algorithm testing continued using various visible and near-IR proxies for the 1.38 micron channel. Contrails were apparent near Cape Cod in one of the early SeaWIFs east coast true color images. The contrail algorithm was successful in retrieving distinct contrails over ocean, but not those contrails having low contrast over land. A series of declassified visible photos from the USGS archive which show a variety of cloud backgrounds was also studied using the algorithm. The goal of this work is to investigate and reduce "false alarms" owing to cloud streets and other linear cloud features. studied using the algorithm. The goal of this work is to investigate and reduce "false alarms" owing to cloud streets and other linear cloud features.

Algorithm refinements are still under development, but several were implemented for testing. The first refinement was to better characterize "ridge" pixels which make up bright linear local features. Another refinement was to modify the straightforward Hough transform in order to prevent the algorithm from trying to connect bright features which are separated by a substantial distance. Contrails are neither very local features nor features which must extend across entire scenes. A final enhancement to the methodology which received some study was to add the requirement that contrail solutions be composed only of ridge pixels which each have the same orientation as the entire contrail. This is expected to reduce false identifications of contrails significantly. All of these refinements are in various stages of implementation and testing. Testing involves statistical studies of the ridge pixel selection and contrail recognition process, as well as direct tests of the effectiveness of the entire contrail detection algorithm in returning a proper mask.

Metadata: The level 2 and level 3 metadata issues for our thin cirrus and contrail algorithm were initially handled by Chu. However, Chu (who works for Yoram) became increasingly reluctant to help in handling the issues, although he promised to help during the October MODIS Science Team Meeting. I had to ask Wei Han, whose main responsibility was to help with the development and refinement of the thin cirrus science algorithm, to take over the work of handling the metadata issues.

Code integration & testing: Most of the work was done by Han. It involved intensive work and quite a bit of “catch up” efforts in a very short time period. Unlike most of other MODIS Science Team members, we started very late in the algorithm development, and we do not have enough funding to support a dedicated person to handle the metadata and delivery related issues. We tried to share the man power with Yoram’s research group. We did a lot of work with the MODIS near-IR water vapor algorithm. In return, Yoram’s group was supposed to help with the metadata and delivery issues for the thin cirrus and contrail algorithm. Initially, Chu volunteered to help. However, by the time just before the code needed to be delivered to the MODIS project, the help from Yoram's group was essentially ceased. We were put into a very awkward position. Basically, we had to start from scratch with code integration and delivery issues. We reported the problem to Yoram Kaufman and Mike King. Both of they were not able to come up with any good solutions at the time. With help from Rich Hucek at SDST, we worked day and night for several weeks, and suffered a lot of pain during the process. By December 10, 1997, we were able to deliver the cirrus code to MODIS project and SDST accepted the code.

3. **Radiative transfer modeling** (*Wei Han, Gao, and Ridgway)* -

Ice particle phase function calculations - Since accurate scattering computations for small cirrus cloud and contrail particles require an exact technique based on directly solving Maxwell's equations, a considerable effort has been spent by Mishchenko in order to further improve the performance of the T-matrix method for larger size parameter ice particles. This effort has resulted in a versatile T-matrix code which is by far the most powerful tool for computing light scattering properties of randomly oriented nonspherical particles. The code includes all recent developments and is publicly available on the web at http://www.giss.nasa.gov. A detailed user guide to this code has been written in the form of a paper submitted to the Journal of Quantitative Spectroscopy and Radiative Transfer. The T-matrix code has been used to further check the accuracy of the modified Kirchhoff approximation in computations of forward scattering for large hexagonal columns and plates.

Monte Carlo code - The framework for the radiative transfer modeling of inhomogeneous thin cirrus cloud fields was also developed by Bill Ridgway. The centerpiece is a Monte Carlo simulation of scattered solar radiance based on (1) sun angle, (2) detector wavelength, position, orientation, and resolution, (3) spatially varying surface albedo and bi-directional reflectance function, (4) conservative Rayleigh scattering and non-conservative aerosol and cirrus scattering, and (5) absorption by atmospheric gases (primarily water vapor). The Monte Carlo algorithm is functional, but some components are still under development. Now the code use a very simple 2x2 surface to demonstrate horizontal variability. Data for k-distribution model of water vapor, carbon dioxide, oxygen, and ozone have been created. Eventually, the Monte Carlo code will be used in our sensitivity studies of thin cirrus corrections.

4. **Data Analysis** (*Han, Gao*,) - We have made further analysis of AVIRIS and MAS data collected during the ARMCAS experiment conducted in June, 1995 and FIRE-II Cirrus Field Program conducted on December 5, 1997. A paper on detecting clouds over arctic region was submitted to the Journal of Applied

Meteorology in September, 1997. Another paper on correction of thin cirrus effects was submitted to the J. Geophys. Res. in November, 1997.

Plans for the next 3 month:

(a): further test the water vapor and cirrus algorithms using existing AVIRIS and MAS data acquired during various field campaigns.

(b): work on algorithms already delivered to MODIS SDST. Although we delivered codes to MODIS SDST, additional work is likely needed when MODIS Toolkit, computer operating system, and various libraries are changed in the near future.

(c): work on the validation plan, particularly on plans for comparison between MODIS derived water vapor values and those from microwave radiometers and operational radiosondes. **Please note that we do not have any one on the recently selected validation team to work with and to help with our water vapor validations**. We may have to work with people outside of the validation team in order to get real help on the water vapor validations. Even though the NASA Validation NRA called for water vapor validation, none of the scientists who can really make contributions, particularly with ground-based upward-looking microwave radiometers was selected.

Publications:

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Wielaard, D. J., M. I. Mishchenko, A. Macke, and B. E. Carlson, Improved T-matrix computations for large, nonabsorbing and weakly absorbing nonspherical particles and comparison with geometric optics approximation, Appl. Opt., 36, 4305-4313, 1997.

Mishchenko, M. I., and A. Macke, Incorporation of physical optics effects and computation of the Legendre expansion for ray-tracing phase functions involving -function transmission, *J. Geophys. Res.*., Submitted, 1997.