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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. **Level 2 and Level 3 metadata for MODIS near-IR water vapor and thin cirrus products**: The metadata issue was mainly dealt by Allen Chu, who needed to constantly chase the ever-evolving standards. Unhappiness and frustrations occurred during the handling of level 3 metadata for the MODIS cirrus reflectance and contrail index images.

2. **Level 2 readers for MODIS near-IR water vapor and thin cirrus algorithms**: The two readers should, in principle, be provided by MODIS SDST. In reality, SDST provided very little support to the level 2 reader for the near-IR water vapor algorithm. Allen Chu made quite a bit of effort to produce the reader for the water vapor algorithm and to integrate near-IR water vapor and aerosol algorithms into one PGE. SDST failed to provide any help with the V2 reader for our cirrus and contrail algorithm, and at the same time SDST blamed individual investigators for not submitting the level 2 algorithms in a timely manner. I feel that SDST should have done a better job before blaming others.

3. **Algorithm Development** (*Han, Gao,, Chu, and Ridgway*) -

   a. Cirrus algorithm - The 1.375-μm channel is affected by absorption from water vapor above and within cirrus clouds. 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 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. If MODIS land algorithms use our cirrus reflectance product, the land products, such as vegetation indices, will be improved.

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.

b. near-IR water vapor algorithm - Our V1 MODIS near-IR water vapor 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 for correction of aerosol effects in our retrieved water vapor values. We 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.

4. **Ice particle phase function calculations -** Mishchenko modified the standard geometric ray optics technique to include Fraunhofer diffraction effects. After the modification, the delta-function transmission peaks in phase functions are reduced. Papers on the subject have been written.

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

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 kdistribution 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.

6. **Data Analysis** (*Wei 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 has been written and submitted to the Journal of Applied Meteorology. Another paper on correction of thin cirrus effects is being written.

Plans for the next 3 month:

(a): deliver the V2 MODIS near-IR water vapor and cirrus cloud algorithms to MODIS SDST, and help with the software integration.

(b): finish the writing of the paper on correction of thin cirrus effects from aircraft and satellite images.

(c): further 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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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.