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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: The combined V2 near-IR water vapor and aerosol algorithm was delivered to the MODIS Project in mid-November of 1997. Some of the metadata and QA parameters actually were not implemented in that version of the algorithm. Allen Chu has been interacting with MODIS SDST, to make changes so that the delivered software is working on newer operating system and with updated tool kit. The required "operator actions" have been implemented into the code and delivered to SDST. Allen Chu decided to postpone till probably December of 1998 to implement the missing metadata and QA parameters, in view of the delay in the launch of EOS AM-1 spacecraft. Kaufman and Gao have identified the need of changes to the science part of the near-IR water vapor algorithm, because some of the MODIS channels used in the algorithm have problems related to low signal to noise ratios and light leakage. These changes will be implemented by Gao after I/O, metadata, and QA parameter issues have been resolved by Chu.

Validation plan: We plan to use water vapor measurements from microwave radiometers, radiosondes, and AERONET to verify water vapor values retrieved from MODIS near-IR water vapor channels. So far, almost no attention has been paid by Kaufman's research group on the validation of MODIS near-IR water vapor product. In view of this situation, Gao has decided to take some actions. Gao and Ridgway have made quite a bit of efforts to find ways to get microwave radiometer data from the archives of DOE ARMS data set. Large volumes of data sets have been ordered and then studied. We have found that seasonal variations of column water vapor values in microwave radiometer measurements are obviously seen. Quality control of the data set is still an issue. For example, column water vapor amounts greater than 15 cm or below zero are present in the data set. Over all, the DOE ARMS microwave radiometer data have values to the validation of our MODIS near-IR water vapor product. We can compare the MODIS water vapor image with the time series of microwave radiometer measurements.

We are also interested in comparing nearly coincident water vapor measurements from MODIS data and from radiosondes released from weather stations. Since the Data Assimilation Office (DAO) of NASA Goddard routinely receives global radiosonde data, Ridgway and Gao has spent some efforts to find out whether we can get part of the data stream. DAO seems unwilling to provide the service of providing the portions of the data stream. DAO claimed that the Goddard DAAC should provide such service. David Starr of Code 913, NASA GSFC, informed us that we should be able to get the radiosonde data from an archive site in Nashville, TN. In the next few months, we will further investigate on how to get the desired radiosonde data, from DAAC or from the archive site in Nashville.

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

Science algorithm: The science algorithm includes two parts: thin cirrus reflectance and contrail detection. The V2 algorithm was delivered to MODIS SDST in early December of 1997. Because the design and interface have been changed at MODIS SDST, quite a bit of modifications to our code have to be made.

Wei Han has been interacting with the staffs of MODIS SDST Science Software Transfer Group regarding the algorithm, and making necessary changes. Wei added “operator actions” in all error messages for MODIS cirrus detection/correction algorithm (MOD_PR06CD) and re-delivered the code to SDST.

Since the code delivery in December of 1997, additional progress has also been made in the science algorithm development.

a) Thin cirrus reflectance: The delivered at-launch version of cirrus reflectance algorithm is simple and fully functional. However, the 1.375-µm transmittance factor for water vapor above and within cirrus clouds were estimated based on latitudes and longitudes. The key in our algorithm for retrieving cirrus reflectance in the 0.4 - 1.0 µm spectral region is to accurately estimate the 1.375-µm water vapor transmittance factor. Great efforts have been made in trying to estimate this factor from MODIS’ imaging data themselves, instead of based on “guessing”. Recently, we have found a method to make such estimation from imaging data themselves. The transmittance factor is derived from the scatter diagram of 1.375-µm channel vs 1.24-µm channel for ocean pixels, and from the scatter plot of 1.375-µm vs 0.66-µm channel for land pixels. The quick sort subroutine in Numerical Recipes is used several times during the derivation. Currently, Rong-Rong Li in Kaufman’s research group is helping in testing this algorithm using spectral imaging data acquired with the NASA JPL AVIRIS instrument. Nearly 40 AVIRIS data cubes are available. Tests have been done for several scenes. We have found that the algorithm works properly for scenes with one layer of thin cirrus clouds. It is not working well for scenes containing very few cirrus pixels. It is also not working properly for scenes with cirrus in different altitudes. Obviously, we still need to do a lot more programming and testing to make the algorithm more robust.

b) Contrail detection: The delivered at-launch version of aircraft contrail detection algorithm is functional. 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. Bill Ridgway has made more efforts in refining the algorithm, to better characterize "ridge" pixels which make up bright linear local features, 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, and to reduce the false contrail identifications significantly.

Validation plan: The development of cirrus reflectance and contrail detection algorithms has always been guided by real imaging data. In the case of developing cirrus reflectance algorithm, AVIRIS data acquired during NASA FIRE Phase II Cirrus experiment in December of 1991 and a few other field programs were used. We have obtained additional AVIRIS data from NASA JPL over same areas with and without cirrus cover. These data are being analyzed. In the case of developing the contrail detection algorithm, images acquired with MAS (AVIRIS does not have sufficiently large area coverage), SeaWifs, GOES, and ground-based upward-looking digital camera, have been used.

3. **Advanced Global Imager (MODIS follow on)**:

Dr. Bob Murphy of NASA GSFC circulated documentations about the Advanced Global Imager (AGI) that will continue many of the measurement series initiated by MODIS. The proposed AGI instrument has 20 channels, instead of 36 channels. Initially, the 0.75-µm channel, which is important for atmospheric corrections for ocean color applications, was not included. Gao as well as other scientists in MODIS Ocean Group quickly pointed out the problem to Bob Murphy. The channel has been restored on the proposed AGI instrument.

Gao also pointed out that if a channel near 0.61 µm is added to AGI, the ability of using AGI for remote sensing of Case II water (turbid coastal water) will be improved dramatically. CZCS, SeaWifs, and MODIS were all designed for remote sensing of Case I water (clean deep ocean water). All these instruments have one channel at 0.55 µm, the next channel at about 0.67 µm. There is a large gap between the two channels. In the coastal environment, the competing factor between back scattering by suspended sediments and liquid water absorption results in a rapid decrease of reflectance with wavelength in the 0.55 - 0.62 µm spectral region. An additional channel centered near 0.61 µm will help to capture the spectral “slope” in the 0.55 - 0.62 µm region. During the last MODIS Ocean Group Meeting, Dr. Wayne Esaias made an arrangement for Gao to make a short presentation about the need of the 0.61-µm channel for remote sensing of coastal water. The presentation was well received. However, there is no room to put an additional channel on the proposed 20 channel AGI instrument. It should be pointed out that the Japanese GLI instrument with 36 channels for ADEOS2 spacecraft has implemented a channel near 0.61 µm. The stated purpose for putting the channel on GLI was not for remote sensing of coastal water.

4. **Radiative transfer modeling**

We have received simulated ice particle phase functions from Dr. Liou’s research group and from Mishchenko. Wei Han recently re-organized a complete set of radiative transfer codes for modeling cirrus cloud reflectances (using Dr. S.-T. Tsay’s DISORT code plus a driver code named STRATS). The codes are quite suitable for our sensitivity studies. So far, we have only made a few modeling studies to make sure that the codes work correctly (by testing against the results published in a book written by Dr. Liou). The codes will be used more often during our future development of MODIS algorithm .

5. **Meeting**

Ridgway, Han, and Gao participated the Atmospheric Group meeting held in St. Michaels, MD in early February. Ridgway described the contrail algorithm. Gao described the cirrus reflectance algorithm and the module for correcting aerosol effects in the near-IR water vapor algorithm. Chu described his application of the algorithm for water vapor retrievals from MAS data (as reported by Kaufman).

Gao, Han, and Ridgway participated the MODIS Science Team meeting held near the end of June, 1998.

Publications:

Gao, B.-C., Y. J. Kaufman, and W. Han, Retrieval of column water vapor amount from MODIS channels near 1 µm, published in the *Proceedings of IGARSS’98*.

Gao, B.-C., Y. J. Kaufman, W. Han, and W. J. Wiscombe, Correction of thin cirrus path radiance in the 0.4 - 1.0 µm spectral region using the sensitive 1.375-µm cirrus detecting channel, accepted for publication by J. Geophys. Res.

Gao, B.-C., W. Han, S.-C. Tsay, and N. F. Larsen, Cloud detection over arctic region using airborne imaging spectrometer data, Accepted for publication by *J. Appl. Meteorol.*.