MODIS Science Team Member

Semi-Annual Report

(Jun - Dec 2000)

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A. FOCUS ACTIVITIES DURING THE REPORTING PERIOD

The most important activities undertaken during this reporting period are the following:

1. Land surface reflectance code development, testing and delivery
2. Global Analysis of MODIS surface reflectance
3. Regional analysis of MODIS surface reflectance
4. MODIS Surface reflectance 8 days composite product
5. MODIS Middle Infrared surface reflectance
6. MODIS Adaptive Processing System (MODAPS)/PI Processing/250m system

1. Land surface reflectance code development, testing and delivery

A. Corrections done to the code for compositing level 3 land surface reflectance from level 2G land surface reflectance products (MOD_PR09A, or PGE 21): tested the code extensively and delivered several versions of the code, which can process 500m-resolution and/or 250m resolution data.

B. Several corrections were done to the code for generating orbital level 3 aerosol optical thickness (AOT) data from level 2 AOT granules (MOD_PR04ORB, or PGE 05.

C. Several corrections were done to the code for generating level 2 land surface reflectance and thermal anomaly products (MOD_PR09, or PGE 11).

2. Global Analysis of MODIS surface reflectance

We conduct our global analysis based on the coarse resolution reflectance product (MOD09CRS) which is pushed automatically to our SCF each time PGE11 is run in MODAPS. This product and the associated level 3 coarse resolution (MOD09A1CRS) are also used by LDOPE to produce global browse data set which are available on line (http://modland.nascom.nasa.gov/browse/8day.cgi). This data set enabled us to produce composites over longer periods of time and to check the aerosol correction approach as well as the overall quality of the product. We used that product and a composite period of other 3 months (July to September 2000, figure 1) to develop and test the new aerosol retrieval method which extends the current aerosol retrieval other brighter target, in addition the new aerosol product has been derived from this data set (Figure 1b). The new approach relies on channel 4,5,6,7 to predict the surface reflectance in 470nm and therefore derive the aerosol optical thickness from the actual signal measured at 470nm, the approach was developed and tested over validation sites as well (see figure 2).

Figure 1: 3 months composite of the surface reflectance product (no aerosol correction) used in the validation of the extended dark target approach.

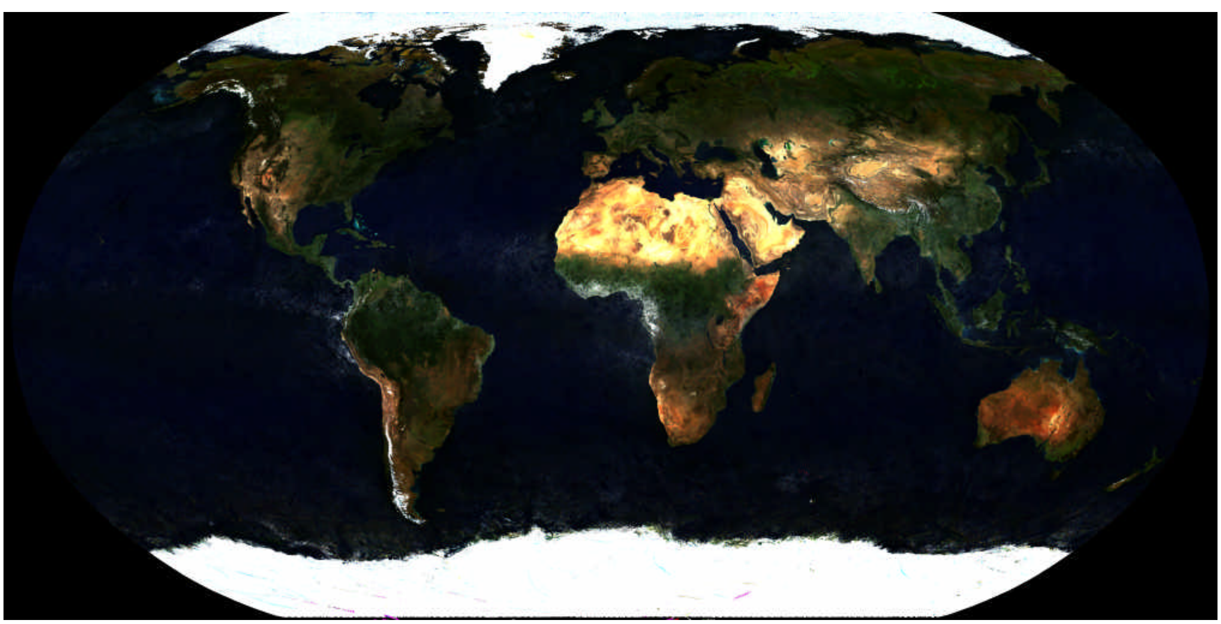


Figure 1b: Aerosol optical thickness (top) and angstrom exponent 8 days composites (265-272 year 2000) derived from the coarse resolution product.

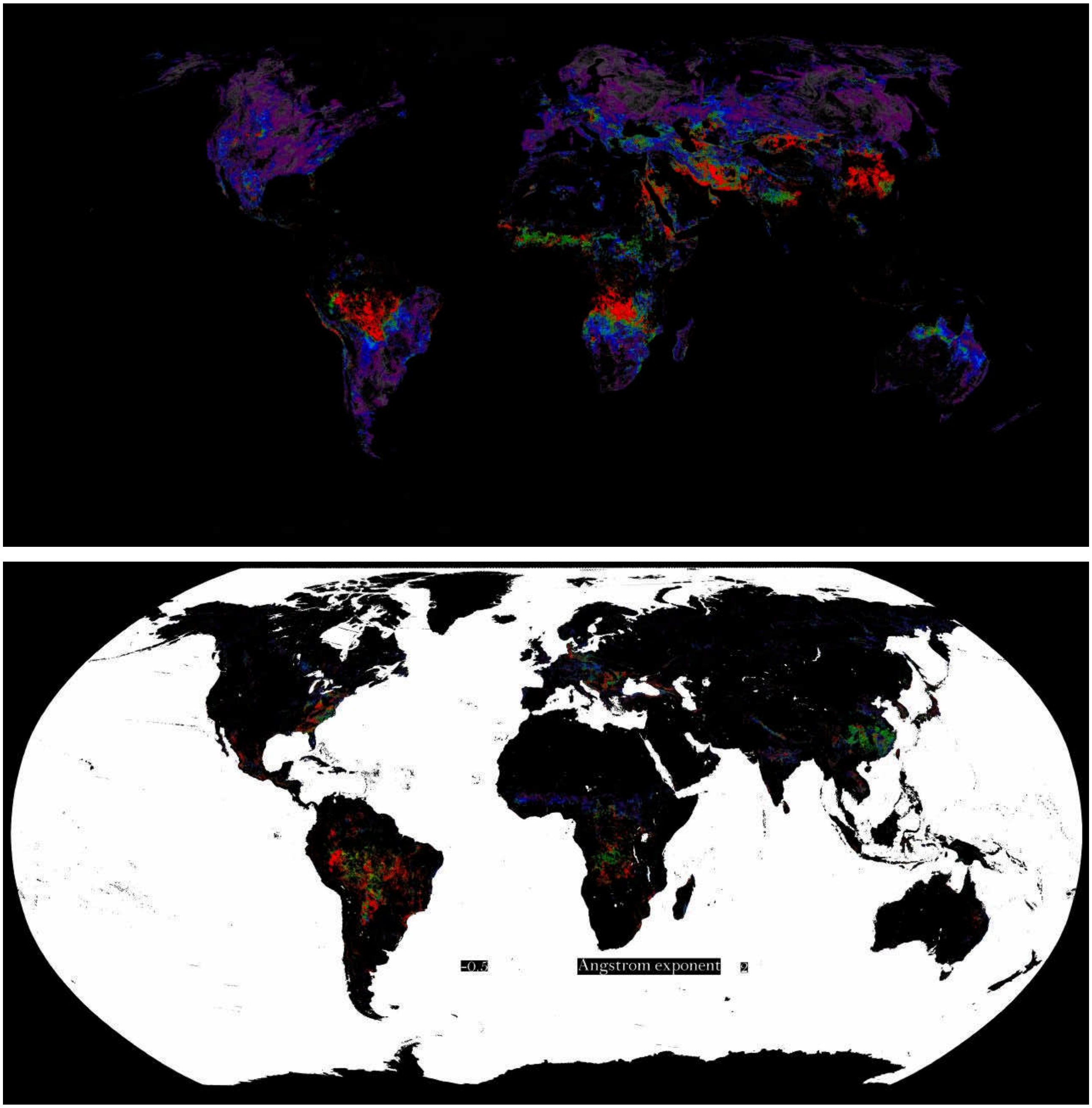
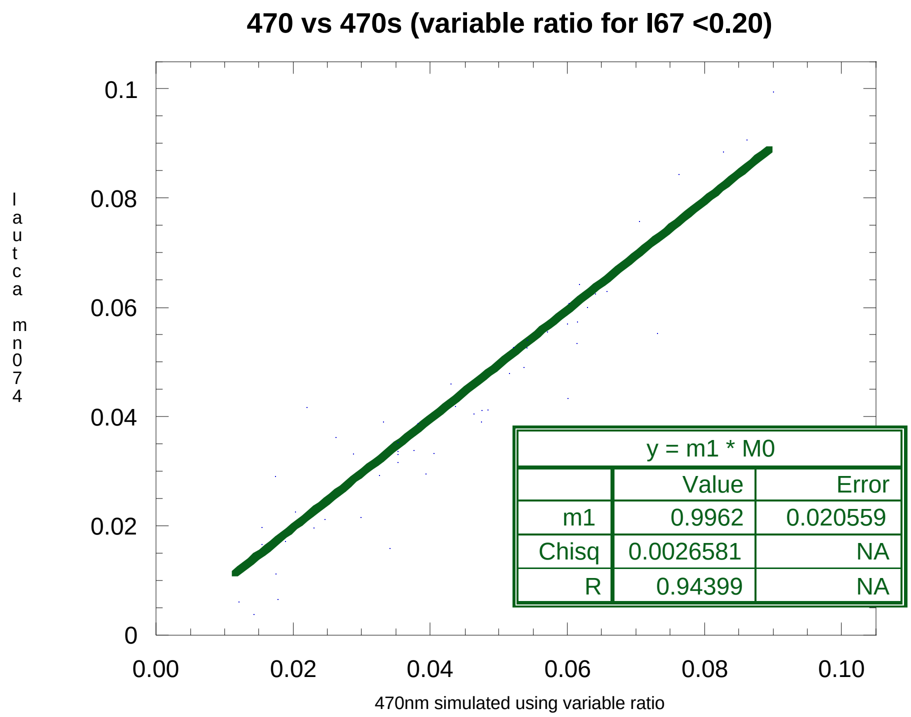


Figure 2: Comparison of the simulated 470nm surface reflectance (X axis) with the actual reflectance (Y axis) over selected validation sites.



3. Regional analysis of MODIS surface reflectance

The MODIS aerosol correction was put in operation on data 273 (year 2000). Globally it performed really well, and improved the accuracy in the downstream product in particular the BRDF/Albedo product suite. Several issues were detected: the sensitivity to snow (which is confused with dark target since it has a low reflectance in the middle infrared), and the limitation of the retrieval to target of up to 0.15 reflectance in the middle infrared (or 0.035 at 470nm). A new version of the aerosol algorithm has been developed by our SCF to address those issues. In addition to filter out snow and extending the retrieval to brighter target, we also retrieved the aerosol at a much higher spatial resolution than the operational version (18km-> 1km) which enables to correct for smoke plumes in the data.

Figure 3: MODIS RGB (left) Level 2 corrected using the new aerosol product (right), the aerosol product represent the optical thickness derived from 470nm. The aerosol optical thickness is not retrieved over water or clouds.

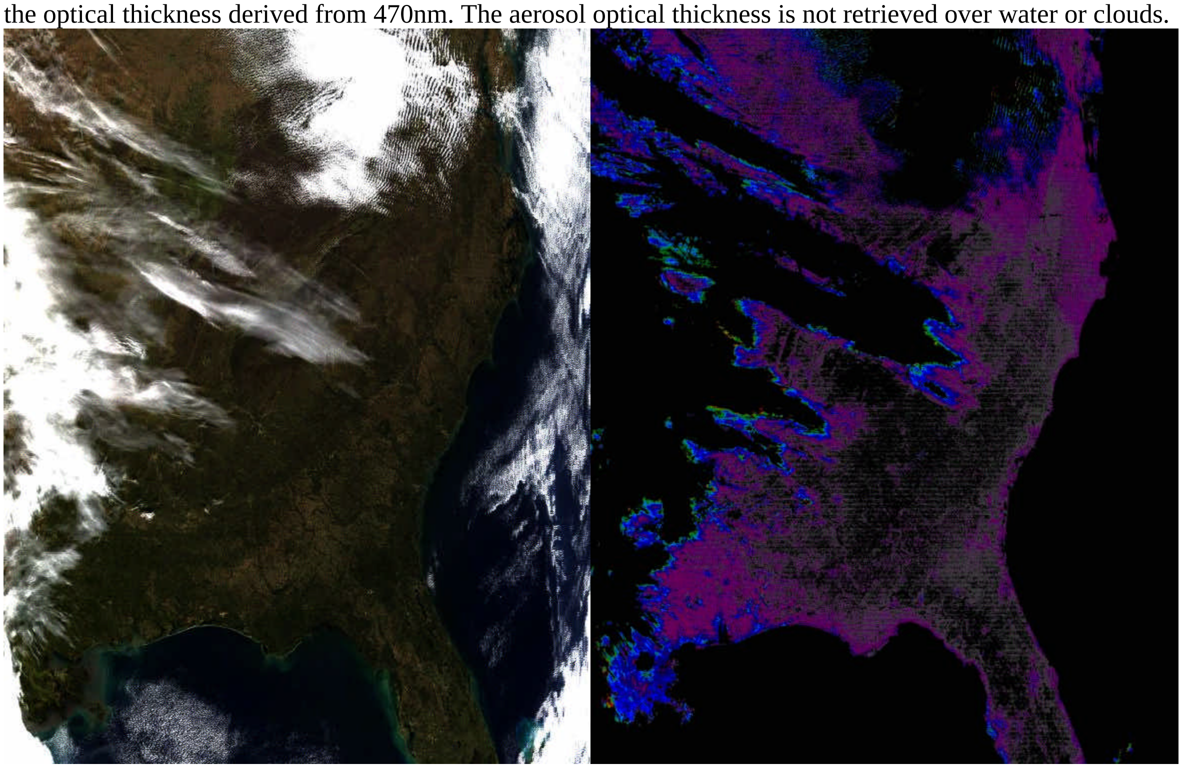


Figure 4a: Detail of the previous scene (uncorrected for aerosols), note the smoke plumes indicated by red arrows.

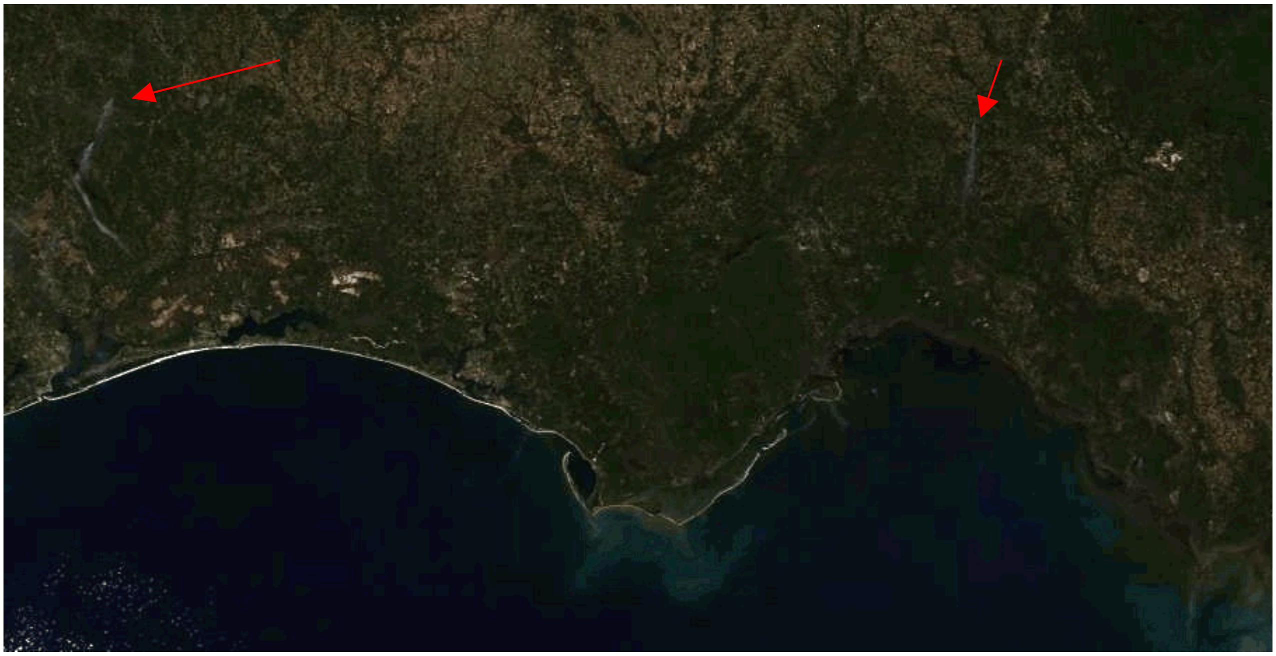


Figure 4b: Detail of the previous scene (corrected for aerosols), note that the smoke plumes (in figure 4a) disapeared

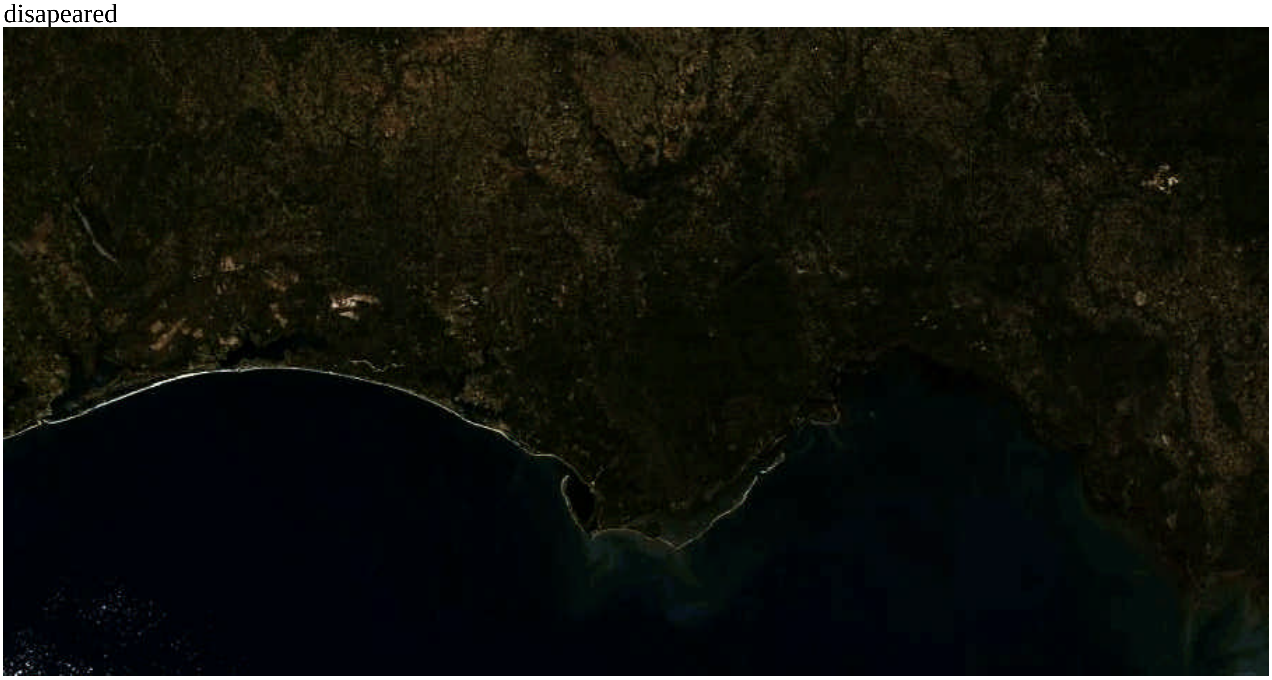
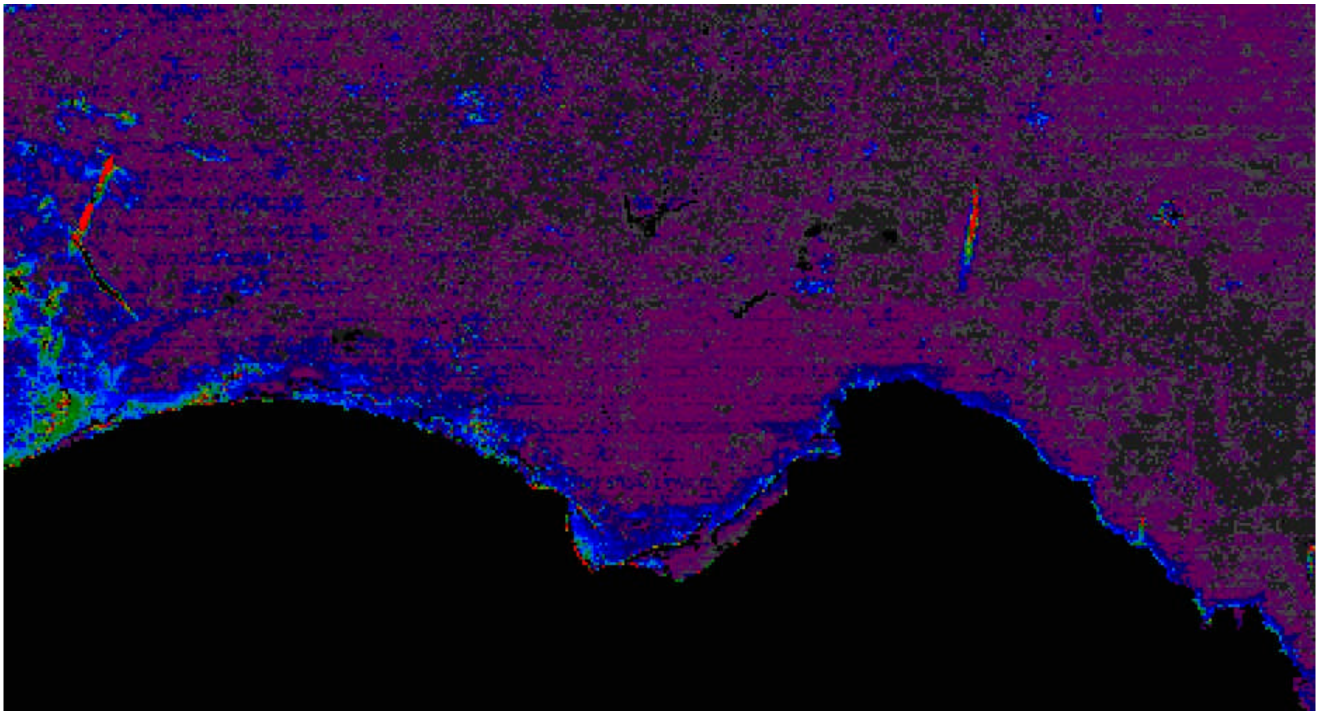
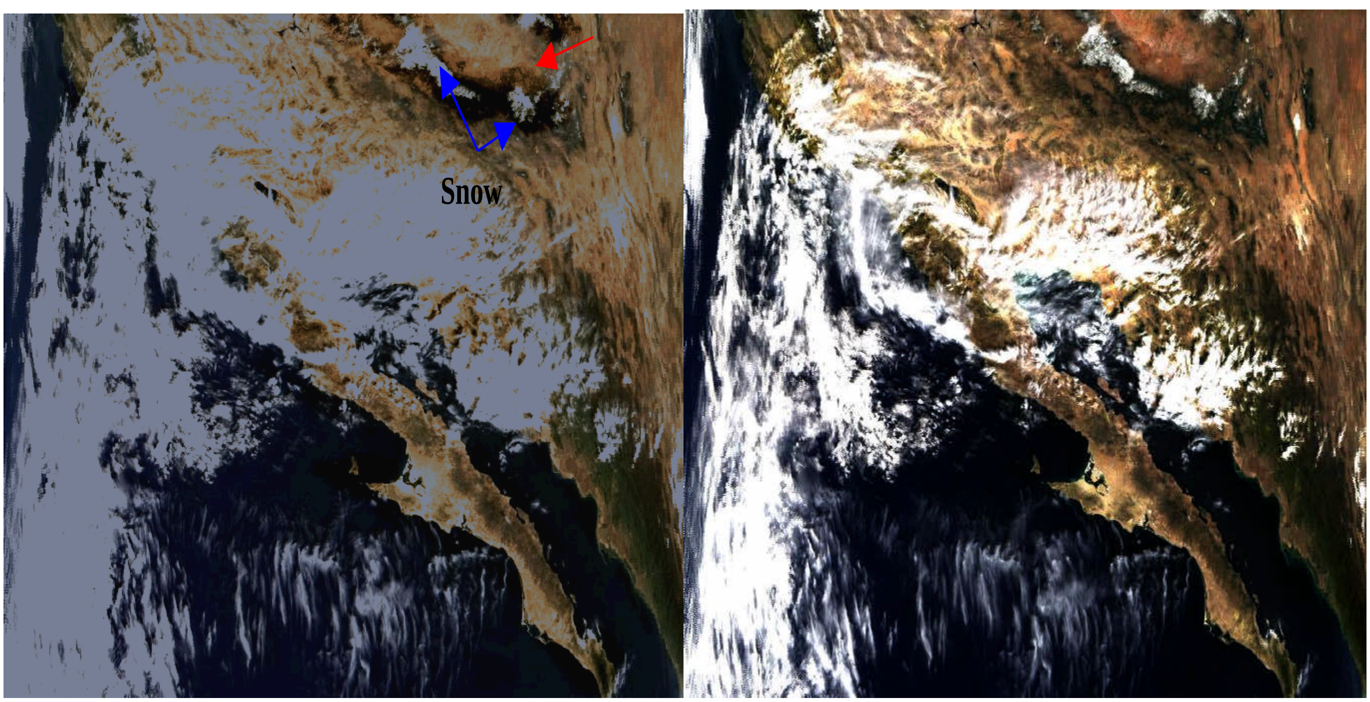


Figure 4c: aerosol optical thickness at 470nm corresponding to figured 4a.



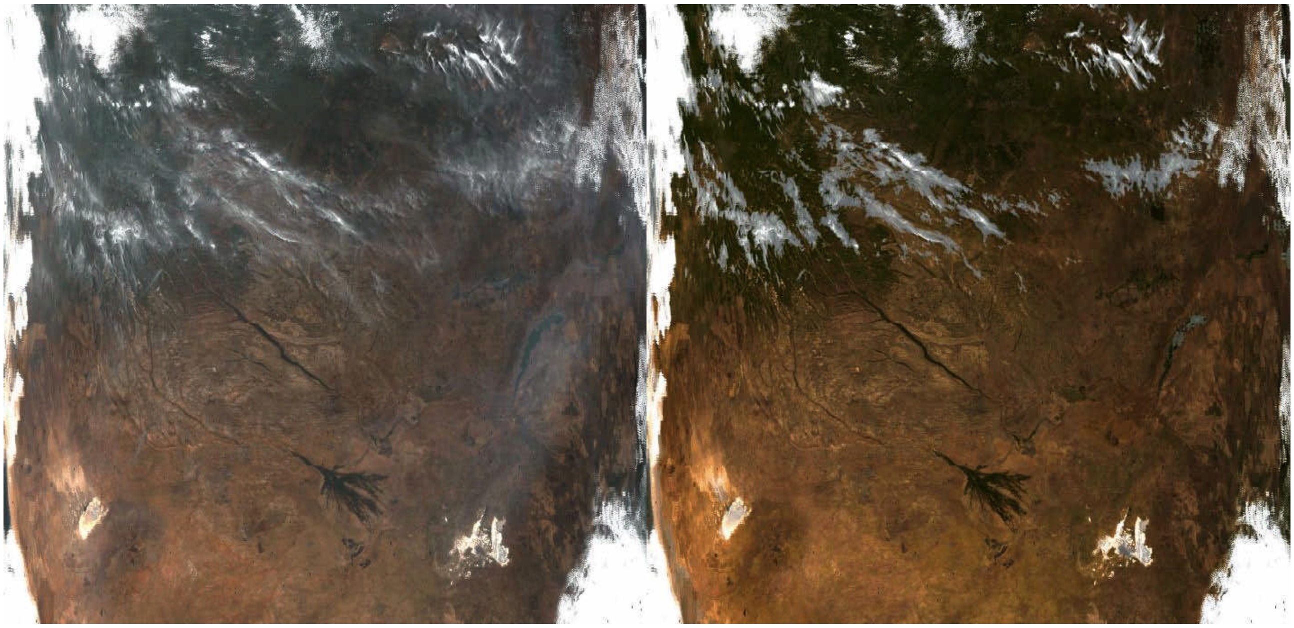
New tests have been added to filter snow pixels or partially filled snow pixels prior to the derivation of the optical thickness. Figure 5 illustrates the problem we encountered with the current aerosol algorithm, the left side corresponds to the production algorithm for the aerosol product, the right side to a new prototype algorithm which additional criteria to filter out snow prior to derivation of optical thickness, the red arrow points to problem area where optical depth is overestimated therefore leading to an over-correction (back-reddish area around the white snow pack), the right side corresponds to the new algorithm, showing the improvement. The suggested approach to filter-out those cases had been communicated to the aerosol team and they are conducting their own evaluation prior to adopting it in the operational aerosol algorithm.

Figure 5: Comparison of the production algorithm results (left side) to the new algorithm for aerosol retrieval (right side) for scenes with snow contaminated pixels.



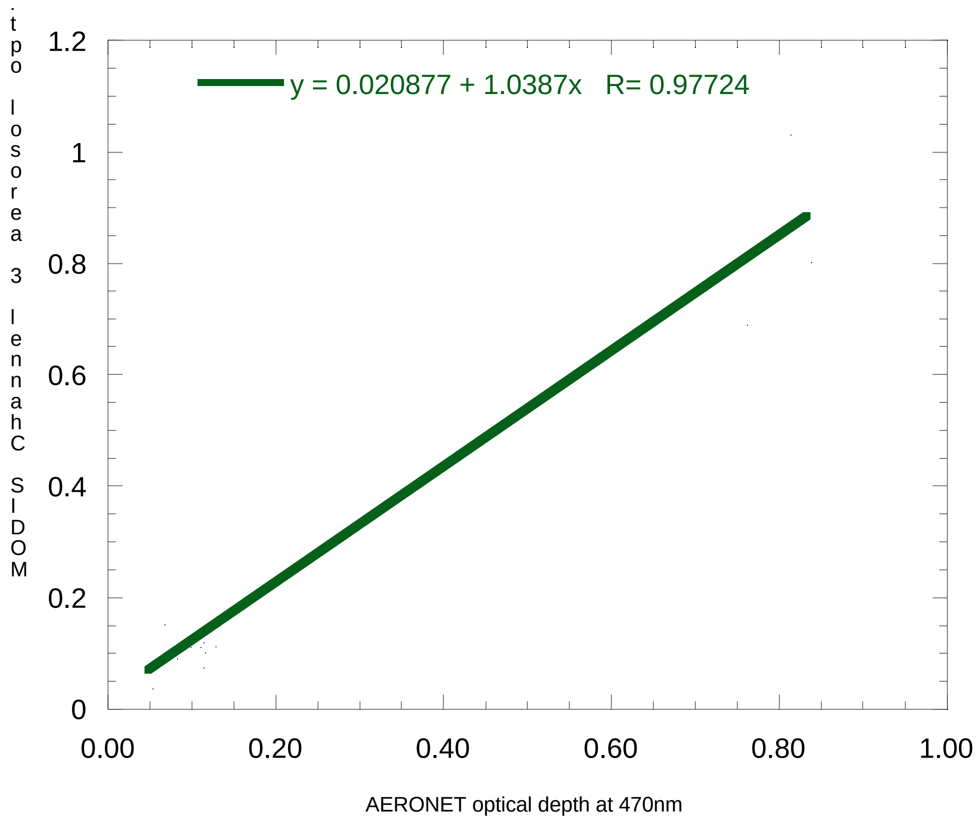
One other important area of improvement has been the extension of the aerosol retrieval to target of reflectance brighter than 0.035 at 470nm. The improvement of this extension is illustrated by figure 6. The left side is the surface reflectance not corrected for aerosol, the right side is the aerosol corrected version, and one can see that no visible artifacts were introduced by the correction.

Figure 6: Evaluation of the new algorithm results over southern Africa, left side corresponds to no aerosol correction, right side to aerosol correction.



The new aerosol algorithm derived aerosol optical thickness have been compared to the AERONET measured optical depth for the couple of scenes processed locally at the SCF; Figure 7 shows the comparison. The values compare very well especially at low optical thickness which is a very important point for the goal of the atmospheric correction algorithm.

Figure 7: Evaluation of the new algorithm results over southern Africa, left side corresponds to no aerosol correction, right side to aerosol correction.



4.0 MODIS Surface reflectance 8 days composite product.

A new algorithm has been developed for compositing the surface reflectance product. It has been motivated by the sensitivity of the currently used method (minimum blue) to cloud/relief shadow and to BRDF effect. With the ability to correct operationally for aerosol, a more rigorous method was needed to avoid selecting off-nadir observation selection. The new approach combines filtering of shadow contaminated pixels with a preferential selection of near-nadir pixels. The new compositing was developed and fully tested at the SCF. The results of the new algorithm are presented for a tile over Eastern United States.

Figure 8a: 8 days reflectance product , top is the production algorithm (minimum blue), bottom is the new algorithm (minimum blue+shadow filter+minimum view angle)

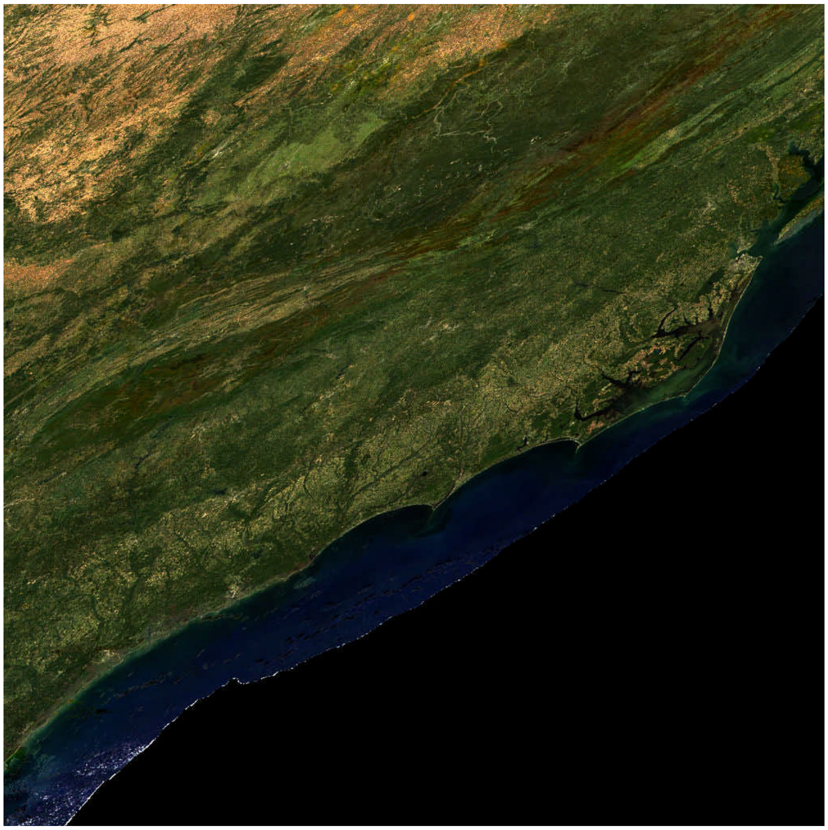


Figure 8b: Same as figure 8a but for a detail of the tile.

5.0 Middle infrared surface reflectance

With surface reflectances in MODIS bands 20, 21, 22 and 23, the MODIS surface reflectance product (MOD09) would be extended up to the middle infrared spectrum (3.5 - 4μm). During the second semester of 2000, the processing scheme of middle infrared surface reflectances was set to a final form and first results were validated.

The two fundamental steps in the middle infrared surface reflectance retrieval are the atmospheric corrections and the removal of the thermal emission. Atmospheric corrections are performed using a radiative transfer approach, with the MODTRAN radiative transfer code on one hand, and atmospheric profiles extracted from a database provided by global circulation model on the other hand. This approach gives access to the radiances at ground level in each of the selected MODIS bands. Thermal emission in the middle infrared is computed using the brightness temperature in thermal infrared (Band 31) and spectral variations of the surface emissivity are taken into account through emissivity ratios. Emissivity ratios are derived from MODIS night-time data.

Figure 9 shows the data flow in the processing, from calibrated radiances (MOD021KM) to middle infrared surface reflectance. Atmospheric corrections require also the geolocation fields (latitude and longitude) as well as the sensor and solar zenithal and azimuthal angles. These six parameters are provided by the MOD03 geolocation product. After radiometric measurements are corrected from atmospheric perturbations, night-time and day-time acquisitions are separated. With night-time data, emissivity ratios are computed using adapted power function to be independent of the surface temperature. Averaged emissivity ratio over a 16-days period of time are produced. With emissivity ratios between one of the four middle infrared bands (20, 21, 22 or 23) and band 31 and the brightness temperature in band 31, the band surface emission in the middle infrared during day-time is computed and the middle infrared surface reflectance is derived from day-time data.

Averaging emissivity ratios over a limited period of time was found to be the best method to remove errors due to instrumental noise, uncertainties in the atmospheric corrections and approximations made in the method. All these errors are independent and can be considered as random with respect to time. Averaging is a powerful filter but we had to verify that the emissivity ratio is not time dependant and do not change significantly with the sensor zenith angle. Both characteristics are verified in Figure 10, where emissivity ratios between band 20 and band 31, collected over four test areas during a two months period of time, are plotted against the sensor zenithal angle. Figure 10 shows that emissivity ratios are stable during the time period and do not present any angular variation if the sensor zenithal angle remains below 55 degrees. Emissivity ratio between band 20 and band 31 is around 0.9 for bare soils and increases as the fraction of vegetation covered surface increases. Results over areas presenting dense vegetation is close to that of water.

For validation purpose, we were in the need of large, homogeneous targets where the middle infrared surface reflectance is known. Ocean and inland water bodies match our needs, with surface reflectance close to zero, glitter conditions excepted. Analysis of results over water is a good validation, but for one value of surface reflectance only. In order to perform validations for an extended range of surface reflectance, we compare measured and model computed middle infrared surface reflectances along a transect cross a figure of glitter.

Middle infrared surface reflectances over 23 areas off the Atlantic southern African shore and over four lakes (Bangweulu and Kariba in Zambia, Malawi in Tanzania and Cahora Bassa in Mozambique) for the period of time starting August 20th, 2000 and ending October 24th, 2000 are collected. Statistical analysis of these surface reflectances is summarized in Table 1. Average values are found less than 1.5% (or 0.015) for all bands but band 21. This band is known as the fire band. With low gain, the saturation of the band is above 500 degrees Kelvin, but the price to pay is a noisy signal at ambient temperature, with a required NeΔt of 2 degree at 300^{o}K. Band 21 is kept in the processing, for future study of fire, but we do not pay much attention on surface reflectance in band 21. Average surface reflectance are lower for lakes than for ocean because inland water generally offer more flat and specular surfaces than open oceans. Standard deviations are lower in band 20, and increase with the wavelength. This is due to a stronger signal (the fraction of solar irradiance reflected by the surface) in band 20 than in band 22 or 23. In half of the cases, minimum and maximum are reasonable values of water surface reflectance. Very low or very high values of surface reflectance are sometime recorded when atmospheric conditions are not stable in the vicinity of the test area. Negative values of surface reflectance correspond to an overestimation of the surface thermal emission in the middle infrared band. Based on this study, we infer that middle infrared surface reflectances are retrieved with an accuracy in the order of 0.02.

Validation of higher surface reflectance is achieved comparing retrieved water surface reflectance under glint conditions and results of the Cox and Munk model [Cox, C and Munk, W, (1954) "Measurement of the roughness of sea from photographs of the Sun's glitter", *Journal of Optical Society of America* 44(11):838-850]. We chose a case study over the Pacific Ocean (around 2.33^{o} South and 139.48^{o} West) and computed the middle infrared surface reflectance of the MODIS granule recorded October 23rd, 2000 at 20:05 GMT. Cox and Munk point out that surface reflectance of ocean under glitter condition is very sensitive to wind speed and to a lesser extend to wind direction. Wind speed and wind direction has been extracted from the NCEP atmospheric database. Figure 11 compare measured and model computed surface reflectances along a line perpendicular to the glint figure at various wavelengths. Surface reflectances in bands 5, 6 and 7 are extracted from the MOD09 surface reflectance product. Along the transect, results in bands 5, 6, 7 and 20 are in good agreements with model computations, except for the largest reflectances where the model underestimates the surface reflectance. Results in bands 22 and 23 are not so good but still within +- 0.02 compared to model computations. With higher wavelength, the solar irradiance decreases rapidly and its reflected part become small compared to the thermal emission.

Algorithm for middle infrared surface reflectance retrieval was set to a stable and final version. MODIS data from August, 20th, 2000 to October 24th, 2000 over Southern Africa were processed at the Surface Reflectance SCF, providing us with a first data set of middle infrared surface reflectance. Analysis of these results shows an accuracy in the order of 0.02. Such accuracy will allow us to use the MODIS band 20-23 surface reflectance product in many application such as aerosol detection, aerosol properties retrieval, BRDF analysis, emissivity and land surface temperature retrieval or enhanced fire detection.

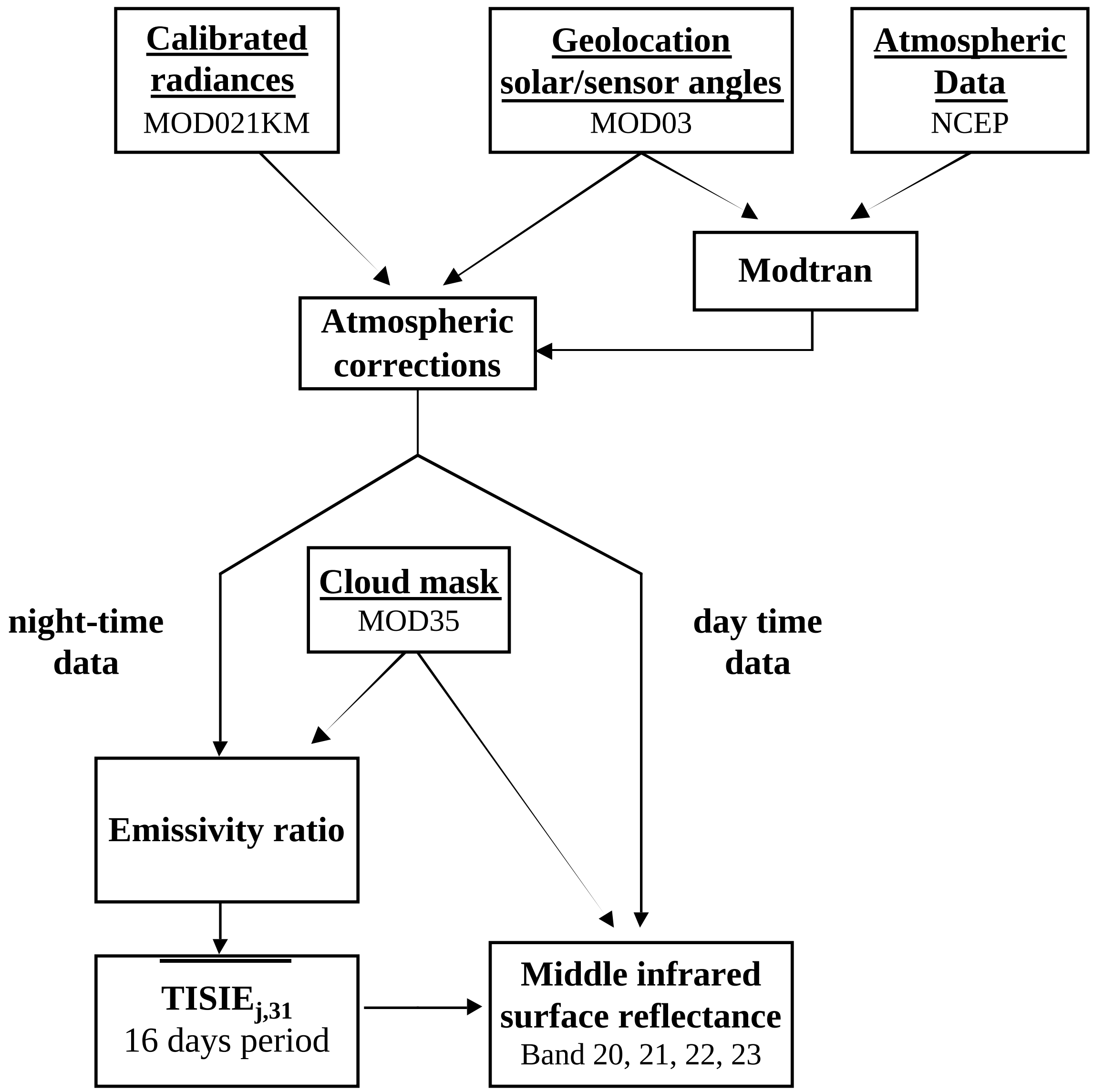


Figure 9: Middle infrared surface reflectance: simplified algorithm scheme and data flow.

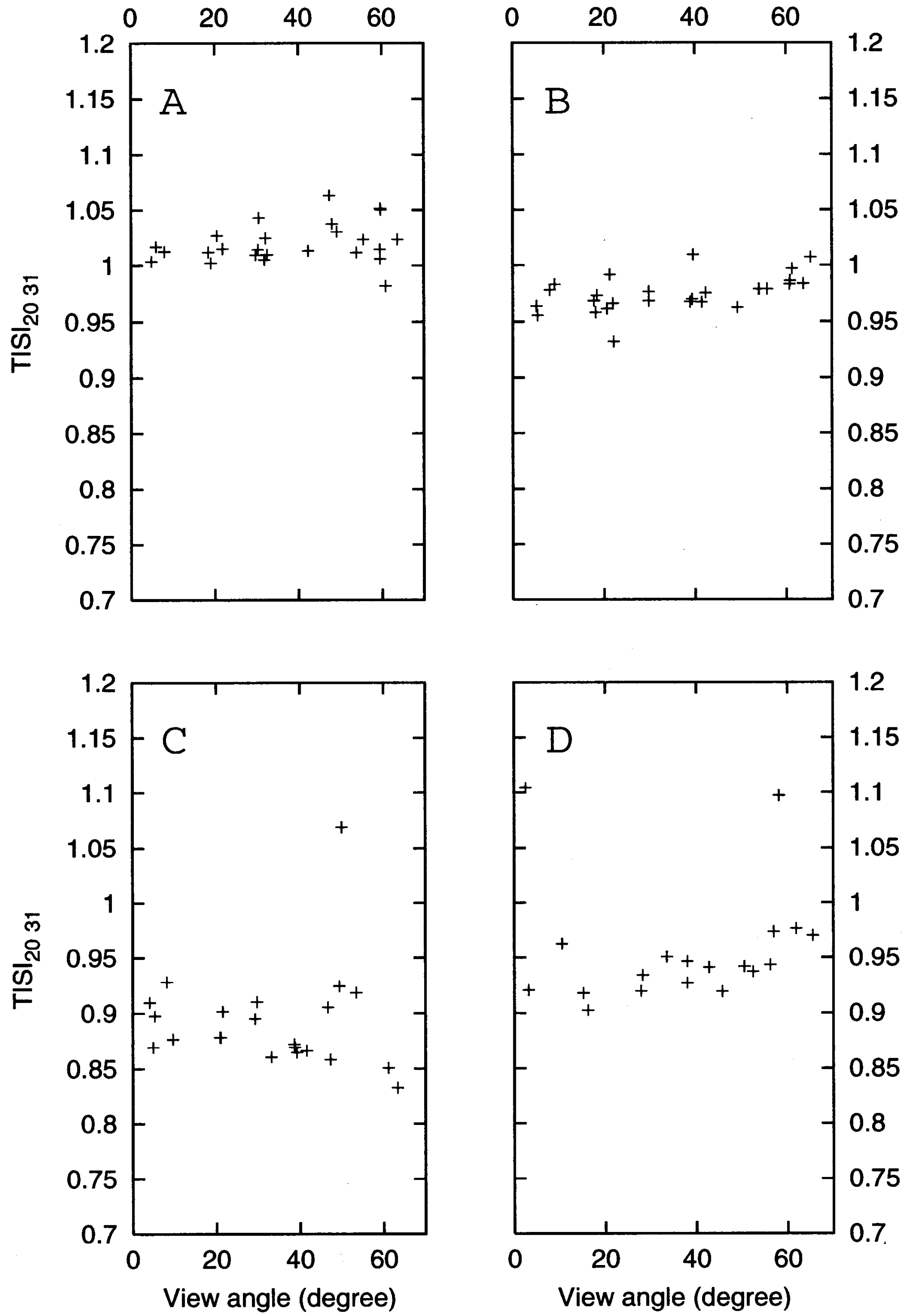


Figure 10: Night-time emissivity ratios between MODIS band 20 and band 31 ($\varepsilon_{20}/\varepsilon_{31}^{2.87}$) for four test areas of southern Africa (IGBP class are: water bodies (A), cropland / natural vegetation mosaic (B), Barren or sparsely vegetated (C) and open shrubland (D)) and for a period of time starting 20th August 2000 and ending 24th October 2000.

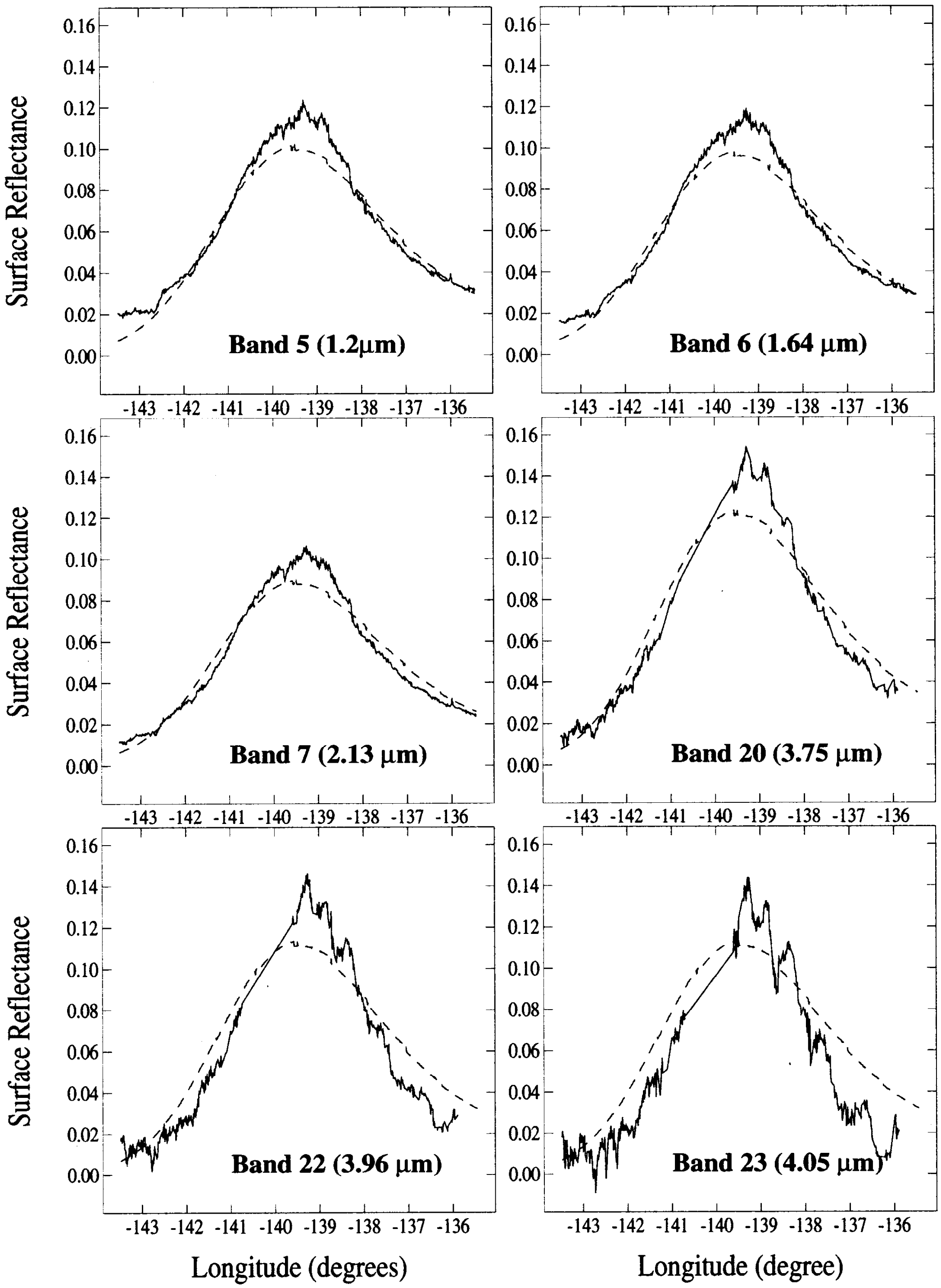


Figure 11: Measured (solid line) and model computed (dashed line) surface reflectances in MODIS band 5, 6, 7 20, 22, and 23 across a glitter figure (MODIS granule August 23rd, 2000, 20:05 GMT, transect centered on 2.33° South, 139.48° West).

Middle infrared	Band 20		Band 21		Band 22		Band 23	
Surface reflectance (%)	ocean	lakes	ocean	lakes	ocean	lakes	ocean	lakes
Average	1.28	0.53	2.11	1.05	1.24	0.07	1.41	-0.40
Standard deviation	1.44	0.57	2.78	2.33	1.48	1.52	1.73	2.24
Minimum	-0.40	-1.60	-3.59	-5.27	-0.60	-4.60	-1.67	-7.07
Maximum	8.78	2.71	13.48	7.94	7.72	6.90	7.77	8.31
Observations	390	67	577	101	501	92	488	89

Table 1:Statistics of middle infrared surface reflectances in band 20, 21, 22 and 23 over water

6.0 MODIS Adaptive Processing System (MODAPS) / PI Processing /250m system

The Land surface reflectance SCF remains actively involved in the PI-led processing activity ranging from making sure that PIs' needs are accurately perceived by the MODAPS development team and by management, to participating in the development of the processing system and various phases of testing.

The SCF participated in the weekly PI-Processing meetings where Eric Vermote represented the land group.

The SCF also participated in all of the weekly MODAPS meetings/telecons where problems were discussed to identify solutions and where progress in the new development was tracked.

Following the SWAMP recommendation to ensure the production of global MODIS data, our SCF participated in the discussions to identify alternatives to the 0.5X MODAPS original production plan. The solution that was adopted was to take the production of the 250m out of MODAPS. A completely independent system generates 10% of the 250m land surface reflectance and VI's so as to provide some data for the PI's to evaluate (see . http://modis-250m.nascom.nasa.gov/). Our SCF played an important role in the shaping of this proposal and in building the prototype production system.

C. MEETINGS ATTENDED

- MODIS Science Team Meeting, Jan,2001.
- Weekly PI Processing Status Meetings, NASA/GSFC.
- Weekly Technical Team Meetings, NASA/GSFC.
- Weekly SDDT (Science Data Discipline Team) Meetings.