Cross Calibration Between ADEOS/AVNIR and OCTS - Error Budget Analysis and The Results from the Field Campaign -

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Kohei Arai
Dept. of Information Science, Saga University
arai@is.saga-u.ac.jp, 1 Honjo, Saga 840 Japan

Abstract

A method for the characterization of surface reflectance for a low spatial resolution of instrument data with a high spatial resolution of instrument onboard teh same platform of low resolution of instrument for vicarious calibration is proposed. An error budget analysis is made for the proposed method. The result shows that arround 5.25% of vicarious calibration accuracy can be achieved if the vicarious calibration accuracy is arround 4.42%.

Keywords: Atmospheric code, ADEOS, AVNIR, OCTS, Vicarious calibration, Field Campaign, Size distribution of aerosol, Aerosol type, Mie Phase function

1 Introduction

According to the error budget analysis for the vicarious calibration, one of the most dominant error source is the EXO Atmospheric Solar Irradiance followed by surface reflectance measurements, optical thickness measurements and estimation and so on. For the EXO Atmospheric Solar Irradiance, so many researchers measured and presented their model for that. Iqubal, Neckel and Labs, Gao, Flierich, Shaw are exampels while the EXO Atmospheric Solar Irradiance in the LOWTRAN-7 and MODTRAN-2 and 3 are another examples for that. They show a not so small discrepancy among them. For instance, Gao and MODTRAN-3.7 shows arround 5% in maximum of difference between both in the visible region while more than 20% in maximum of difference in the shortwave infrared region. In the surface reflectance measurements, there are so many error factors such as stability of the instruments, non-Lambertian surface effect, calibration accuracy of the ground measuring instruments, temperature dependency of the instruments and so on. The most difficult thing in the optical thickness estimation is selection of aerosol type, size distribution, etc. In order to estimate those, we used to use curve fitting between optical thickness measurement data and model derived optical thickness. If we think only the aforementioned three error sources of 2.5%, 2.5% and 2%, then the Root Sum Square error is 4.062%.

This paper describes the proposed method for characterization and estimation of the surface re-

flectance for the area corresponding to one pixel of the low resolution of instrument with simultanuously observed high spatial resolution of instrument data. Error budget analysis will be followed beginning with error budget analysis of the vicarious calibration for high spatial resolution of instruments followed by sampling error(including mis-registration) and the difference of spectral responses between the two instruments(high and low spatial resolution of instruments) in terms of Atmosphric influences and spectral surface reflectances.

2 The Proposed Method

In particular, it is suspected that a large error in the surface reflectance measurements for a low spatial resolution of instrument such as AVHRR, MODIS as well as OCTS because it takes a long time to measure the surface reflectance and BRDF for the areas corresponding to the one pixel of the low resolution of instruments, 700 m x 700 m for OCTS and 1,000 m x 1,000 m for MODIS. This imply that more than 2.5% of error is caused by the characterization and estimation of the surface reflectance. In order to reduce the error, the following method is proposed. Instead of making measurements for surface reflectance for the wide areas, characterization and estimation of the surface reflectance with simultanuously observed high spatial resolution of instrument data and the measured surface reflectance for the areas corresponding to the one pixel of a low resolution of instrument is capable. The error factors in the proposed method are

- Vicarious calibration for the high spatial resolution of the instrument
- Sampling error and registration error between high and low spatial resolution of instruments
- Different atmospheric influences and spectral reflectances between both instruments caused by the different spectral responses.

3 Error Budget Analysis

3.1 Vicarious calibration accuracy for the high spatial resolution of instrument

3.1.1 Vicarious Calibration

The methods for a vicarious calibration so called the radiance based, the reflectance based and the improved reflectance based methods were proposed by several *institutes*[1],[2],[3].
Essentially the reflectance and the improved reflectance based methods use Sunphotometer data derived optical thickness of the atmosphere and the BRDF and the spectral reflectance of the surface of interest as well as an atmospheric code including a Radiative Transfer Code, RTC. Based on the BRDF and the spectral reflectance and the optical thickness of the atmosphere, the radiance at the top of the atmosphere so called TOA radiance is estimated with the atmospheric code. On the other hand, the radiance based method uses aircraft data. The difference between the estimated radiance at the certain altitude(the aircraft altitude) with the BRDF, the spectral reflectance and the optical

thickness and the measured radiance(the aircraft data) is compensated in the TOA radiance estimation. A sensitivity analysis was conducted and reported for the aerosol complex refractive index, the aerosol size distribution and so on. Meanwhile Aureolemeter gives the phase function with some error. In the calculation of multiple scattering due to aerosol particles with the doubling method, some approximations for Mie phase function are *required*[4],[5].
In this paper, the sensitivities of the atmospheric parameters and the geometric relationship among the ground cover target, the sun and the satellite are evaluated with field campaign data for the vicarious calibration of ADEOS/AVNIR(one of the examples of high spatial resolution of instrumnets).

3.1.2 Error Budget Analysis for the Vicarious Calibration

Table 1 shows the results from the error budget analysis for the vicarious calibration.

Table 1 Error budget for the vicarious calibration for ADEOS/AVNIR

Error Source	Error in %	Remarks
Optical Thickness Measurement	1	
Curve Fitting for Size Distribution and Refraction Index Estimation	2	
Surface Reflectance Measurement including BRDF Measurement and Correction	2	For both the Standard Panel and the surface of test site
EXO Atmospheric Solar Irradiance	2.5	
Mis-Registration	1	
Accuracy of Radiative Transfer Code	1	
Root Sum Square Error	4.15%	

3.1.3 The field campaign for the vicarious calibration of ADEOS/AVNIR

AVNIR is the high spatial resolution of visible to near infrared instrument onboard ADEOS satellite for multi-purpose mission including agricultural and forest inventory, land use, digital elevation model and so on. The satellite was launched in August 1996 and was terminated in June 1997 due to mulfuntion of the solor panel.

One of the post launch calibration activities is the field campaign for the vicarious calibration of the AVNIR and was conducted three times, at the Calfornia offshore in November 1996, at the Rogers Dry Lake and Ivanpah Playa in Feburary and March 1997 and the Calfornia offshore in May 1997. In the field campaign at Ivanpah Playa on March 4 1997, our team measured solor irradiance with our Sunphotometer(5 channels), sky light with the Aureolemeter, surface reflectance, surface BRDF as well as standard panel of Labsphere Spectralon. Weather condition was not so good because two days before that day, we had the rainfall so that the atmospheric condition is not stable and the surface was getting dry gradually. Therefore I took the modefied Langley Plot other than Langley Plot. On the day for vicarious calibration, March 4 1997, we had a dry atmosphere.

Table 2 Conditions on the field campaign for vicarious calibartion of AVNIR in March 1997

Date	Location	Sunrise	Overpass time	Solor Noon	Pointing Angle
1997/3/4	Ivanpah Playa	6:07	10:49:59	11:52	3.6
Surface Pressure	Humidity	Temp.	Solor Az.	Solor Zenith	
930(mb)	48(%)	284(K)	156.8	45.0	

Fig.1 to 6 show the location of the test site, Ivanpah playa, Nevada USA, the surface reflectance, Optical thickness due to molecular, aerosol and total, and TOA radiance normalized by Solar irradiance rpovided by MODTRAN-3.7, so called Normalized TOA radiance, respectively. Through a comparison between the calculated TOA radiance(45.25, 52.63, 69.64, 110.02(W/m^2srum) for AVNIR band 1 to 4)and the converted AVNIR radiance from AVNIR Digital Count Value(43.25, 51.00, 68.11, 104.15(W/m^2srum) for AVNIR band 1 to 4), there were -4.5, -3.1, -2.2, -5.6(%) of differences between them.

3.2 Characterization and Estimation of Surface Reflectance

The next thing we have to do is to register the high spatial resolution of instrument data onto the low spatial resolution of instrument data. Through a visual matching between the two imagery data on the display, two instrument data are registered with a few 10th of pixel of error.

3.3 Difference of Spectral Responses Between Two Instruments

Fig.7 and 8 show the spectral responses of AVNIR and OCTS, respectively. Both are overlapped so that it is possible to generate AVNIR spectral response with OCTS spectral response through weighted linear combination of OCTS spectral response. Using MODTRAN-3.7, the weights for the linear combination are calculated and are 27.7, 39.8 and 32.5 for OCTS band 1, 2 and 3, respectively for the generation of AVNIR band 1 and are 56.8 and 43.2 for OCTS band 4 and 5 for the generation of AVNIR band 2. Fig.9 and 10 show the relationship between the generated AVNIR band 1 from OCTS band 1, 2 and 3 and the generated AVNIR band 2 from OCTS band 4 and 5, respectively. Fig.11, 12 and 13 show the original AVNIR image(false colored), the simulated OCTS band 1+2+3 image from AVNIR by averaging over 44 by 44 pixels and the real OCTS band 1+2+3 image of Ivanpah Playa in Nevada, U.S.A. on March 4 1997. Using these OCTS band 1+2+3 and OCTS band 4+5 data from AVNIR data as well as a virtual center wavelength of OCTS band 1+2+3 and band 4+5, we can estimate OCTS band 1 to 5 from AVNIR data. Then we can conduct vicarious calibration of OCTS using the calibrated AVNIR.

3.4 Calibration Accuracy for the Proposed Method

Taking Root Sum Square for the aforementioned factors, we concluded that the calibration accuracy of the proposed method is arround 5.02%(Vicarious Calibration Accuracy of 4.15%, Characterization and Estimation of Surface Reflectance Including Mis-Registration of 2% and Difference of Spectral Responses(Atmospheric Influences and Spectral Reflectance) of 2%).

4 Concluding Remarks

Through the field campaign, the radiance from ADEOS/AVNIR was comfirmed with some discrepancy within +/-5.5(%) against the vicarious calibration data. According to the reflectance based method, around 5(%) is the most possible accuracy so that +/-5.5(%) difference is not so large. Through the sensitivity analysis, it is confirmed that the most significant factor on the TOA calculation in the vicarious calibration is the imagenary part of the complex refractive index of aerosol followed by phase function so that the accuracy of Aureolemeter is very important. It is also fount that the calibration accurcay of the proposed method is arround 5.02%.

References

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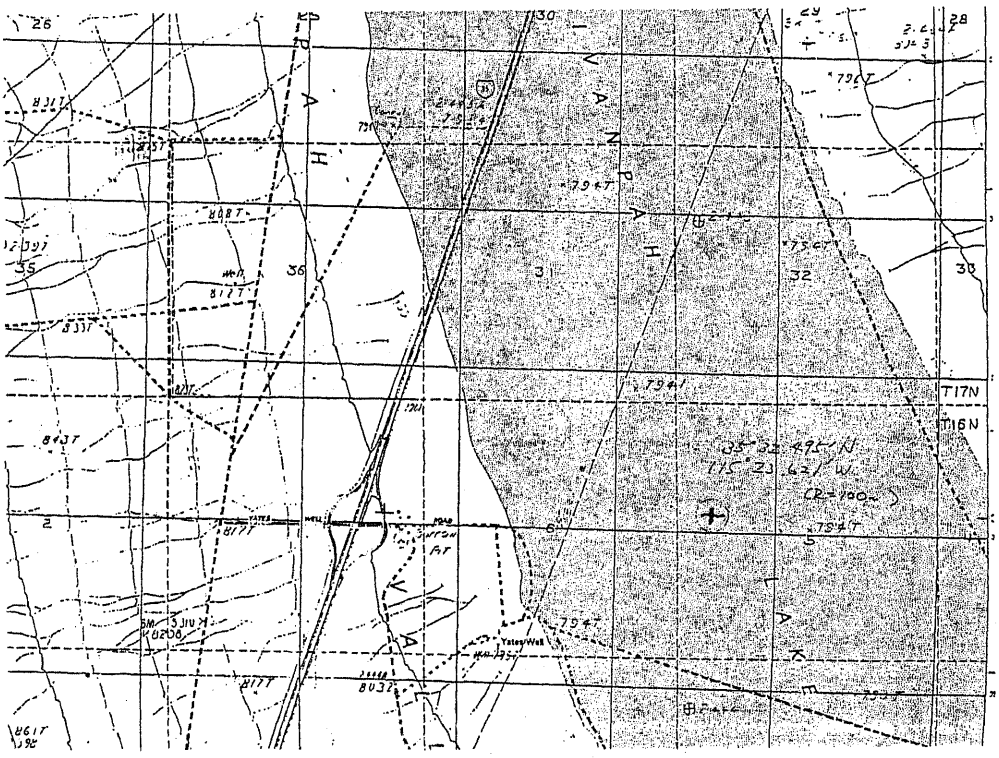

Fig.1 Location of test site,Ivanpah playa in Nevada, U.S.A.

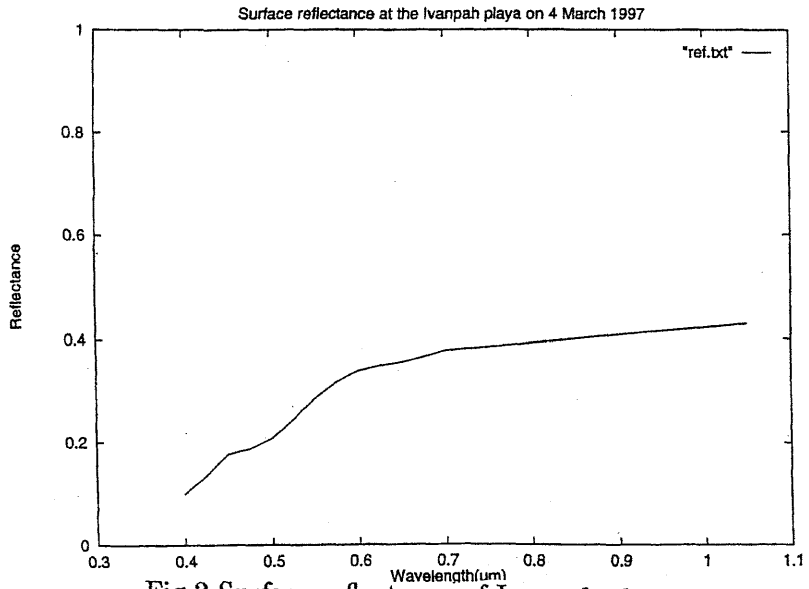

Fig.2 Surface reflectance of Ivanpah playa.

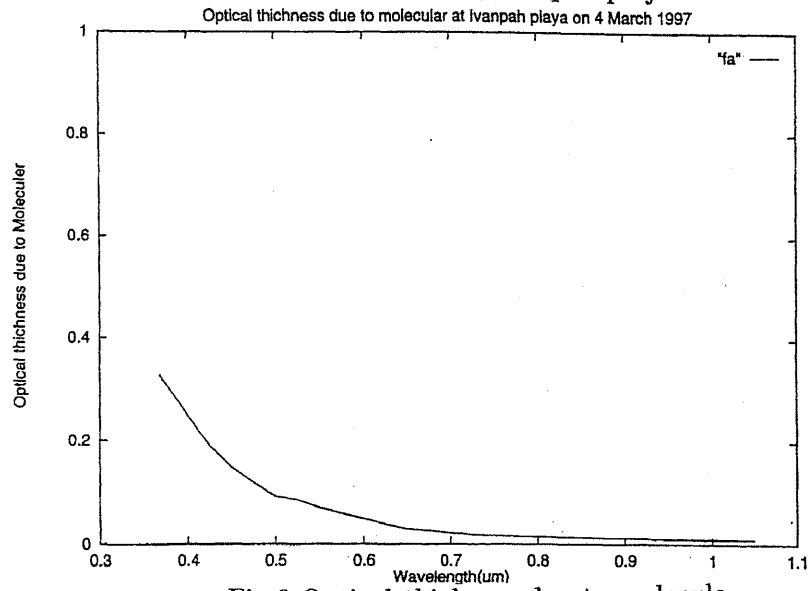

Fig.3 Optical thickness due to molecule.

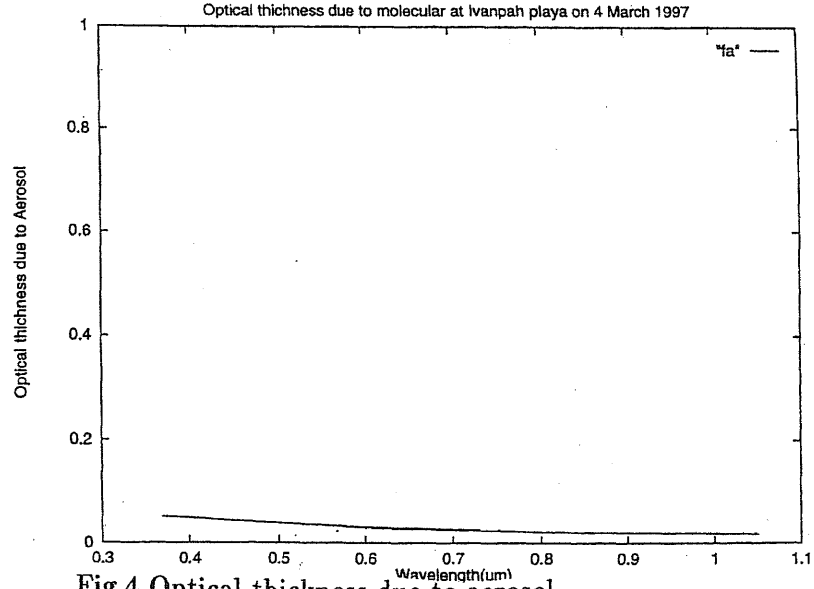

Fig.4 Optical thickness due to aerosol.

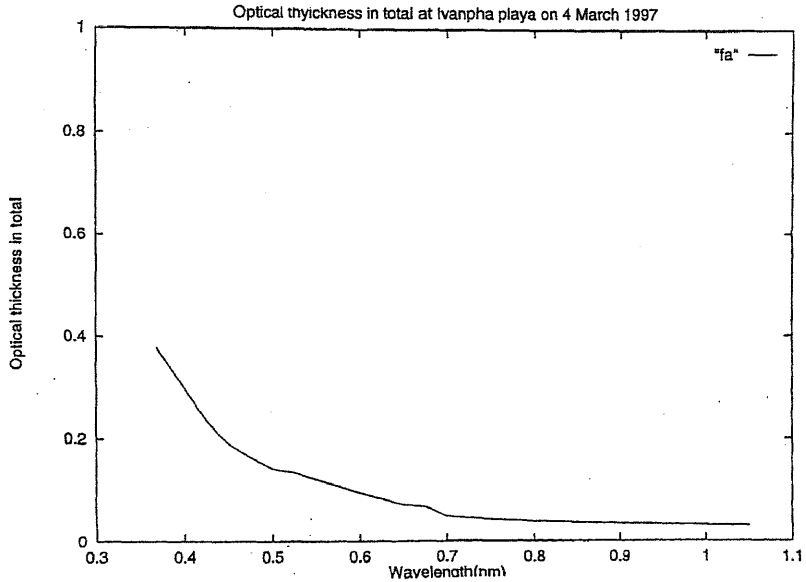

Fig.5 Optical thickness in total.

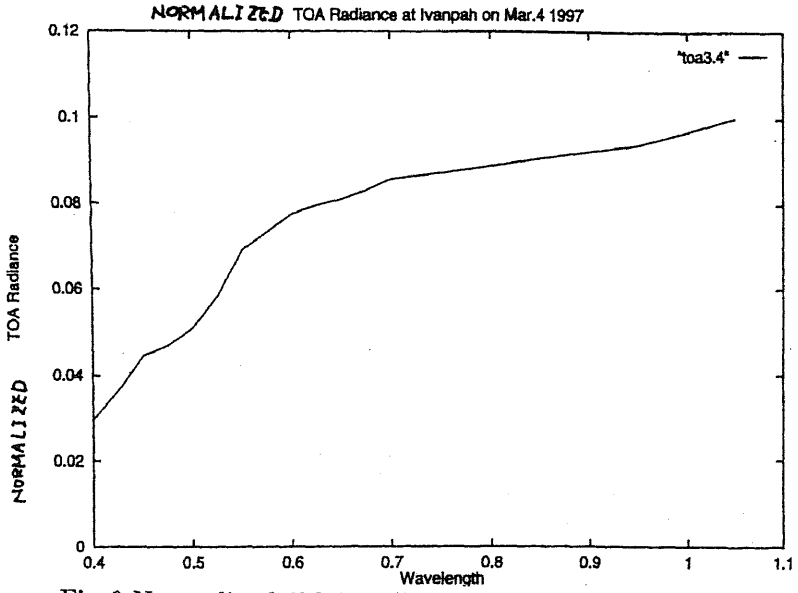

Fig.6 Normalized TOA radiance.

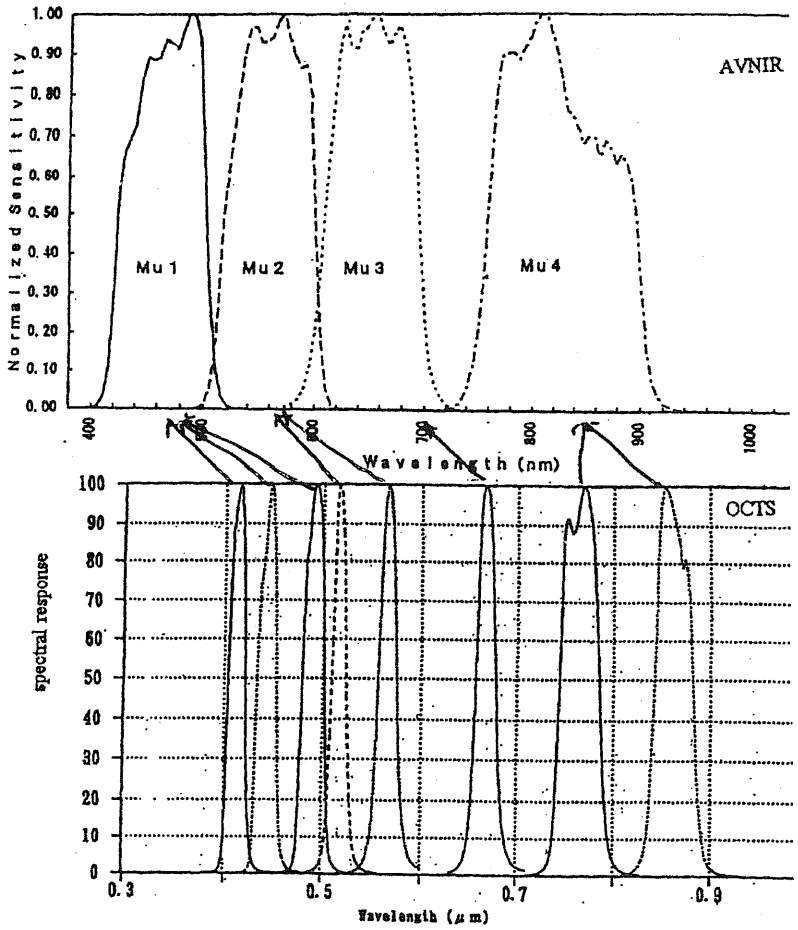

Fig.8 Spectral response of AVNIR. Spectral response of OCTS.

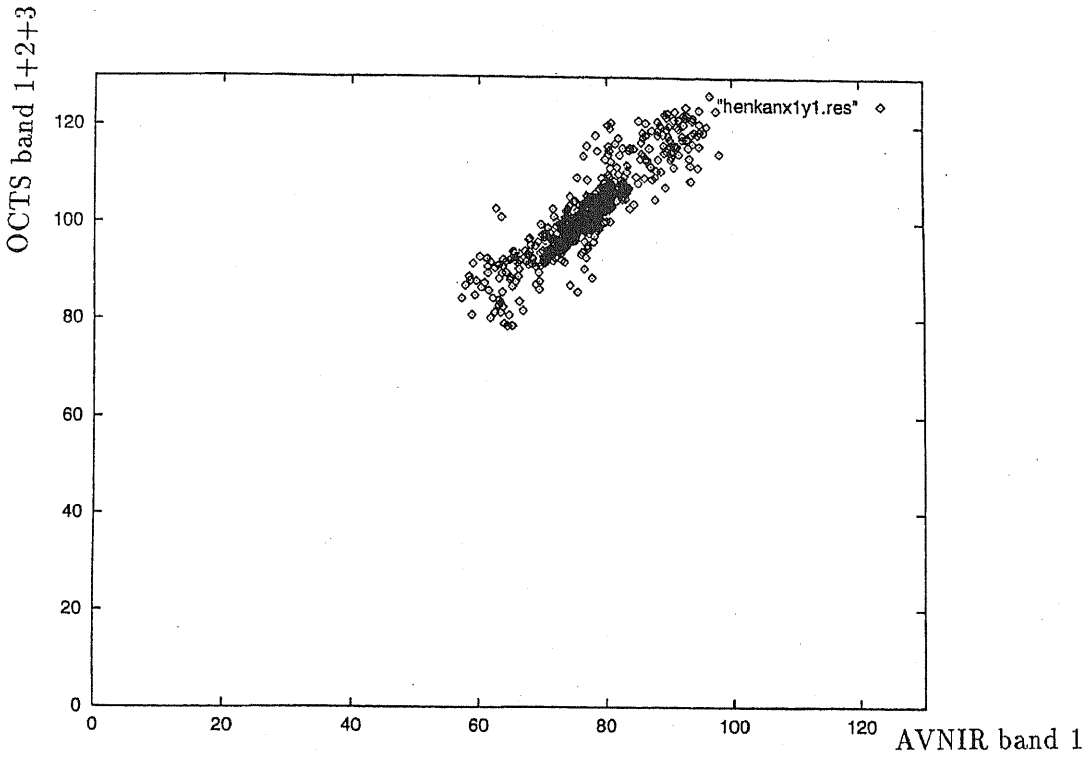

Fig.9 A relationship between the generated AVNIR band 1 and OCTS band 1+2+3.

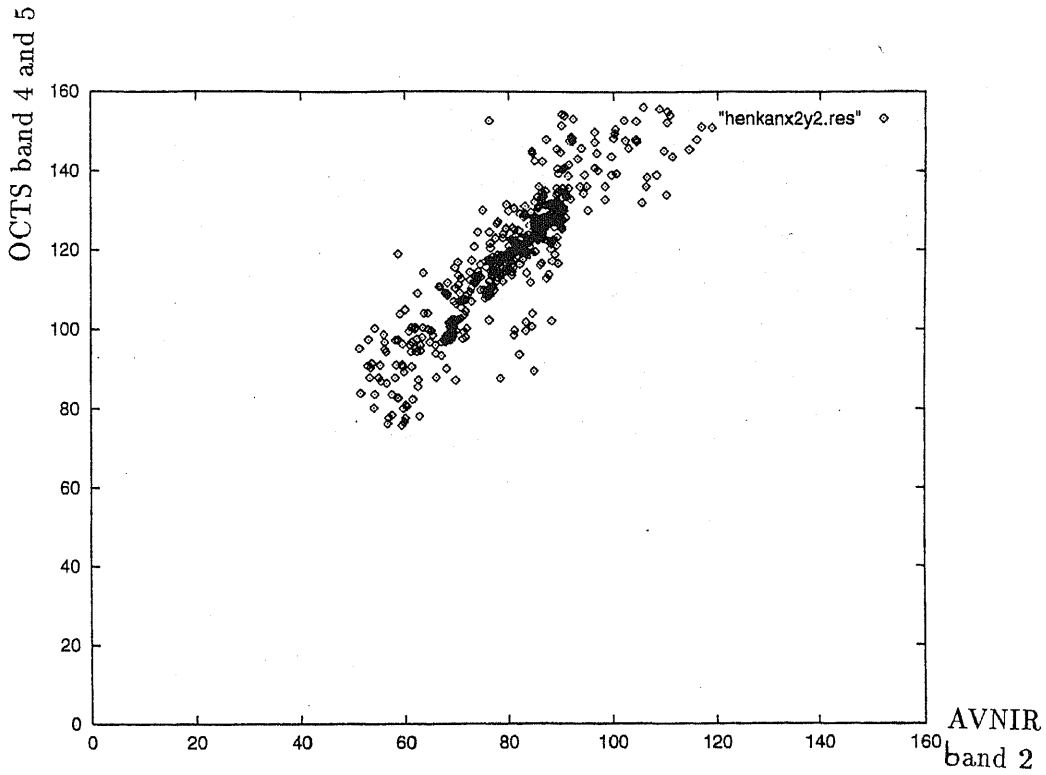

Fig.10 A relationship between the generated AVNIR band 2 and OCTS band 4 and 5.

Fig.13 The real AVNIR band 1 image

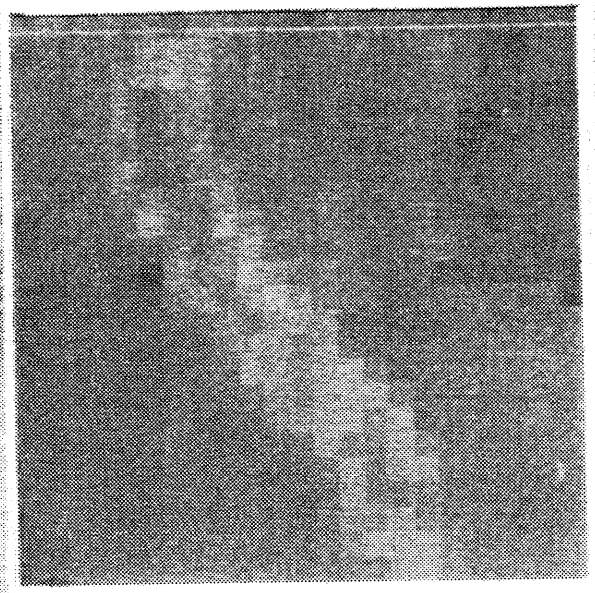

Fig.11 The generated OCTS band 1+2+3 image from AVNIR band 1, 2 and 3.

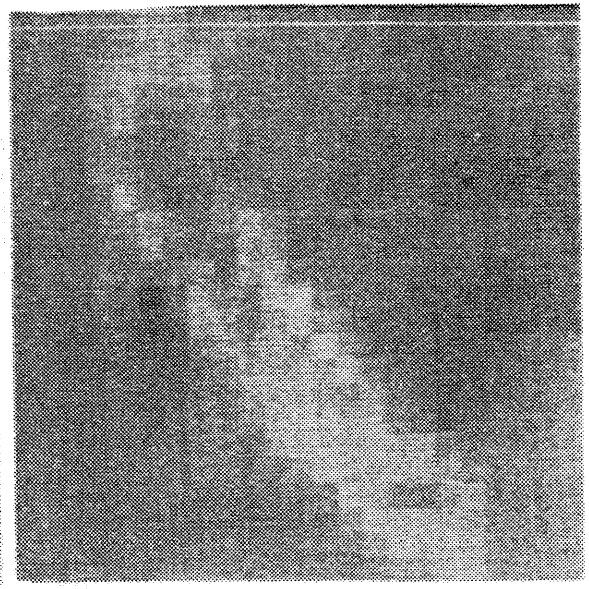

Fig.12 The real OCTS band 1+2+3 image