GEOMETRICCONSIDERATIONOF IMAGE COMPOSITE FOR VEGETAION MONITORING
—— NOAA/AVHRR, ADEOS/OCTS, ADEOS-II/GLI ——

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ABSTRACT:

NOAA/AVHRR data are widely used for vegetation monitoring, especially in a global scale. National Space Development Agency of Japan (NASDA) is planning to develop newearth observation satellites like ADEOS (Advanced Earth Observing Satellite), ADEOS-II, etc. Some sensors on these satellites willbe expected to be applied to vegetation monitoring. Ocean Color and Temperature Scanner (OCTS) on ADEOS and Global Imager (GLI) on ADEOS-II will be useful for this purpose. The former has the spatial resolution of 700m at nadir and the latter has of 250m in visible and near infrared regions. These sensors willbe able to play the same as or better role than AVHRR because of their higher resolutions.
For vegetation monitoring, some images observed sequentially are composed to one image for eliminating clouds. The author already proposed the method of image composite for NOAA/AVHRR with the considering on the solar zenith angle effect on NDVI, the distortions in both geometry and radiometry, the revolution of satellite.
If OCTS and GLI images are of integrated use with AVHRR image, the cross calibration will have to be examined, because they have differences in geometry like spatial resolution, revolution, orbit, solar zenith angle at observation, etc. That results in the radiometric characteristics of composite image of AVHRR, OCTS and GLI are different.
In this paper, the attentions to pay for image composite are pointed out with respect to geometric properties, and the method of image composite is proposed.

1. INTRODUCTION

Since the discussion on the global environment was begun in 1980's, NOAA/AVHRR data have been widely utilized in the field of vegetation monitoring. For example, GVI data have been produced from AVHRR data by NOAA/NESDIS and used for global vegetation monitoring. Vegetation map of 1km resolution is also prepared. ADEOS/OCTS and ADEOS-II/GLI developed by NASDA will be expected to be applied to this field. The spatial resolution and spectral property (number of bands) of these sensors are better than those of NOAA/AVHRR, while the observation of the same area is less frequent. It seems that the best way to utilize the OCTS and GLI data to vegetation monitoring is the integrated use of these data and AVHRR data so as to take advantages of each sensor data. It means to make use of the high resolutions and high spectral properties of new sensor data and the frequent observation of AVHRR data.

It is supposed in this paper that image composite willbe generated from sequential images of each sensor for a certain period. These composite images from three kinds of sensors are integratedly used for vegetation monitoring. In order to conduct such an application, the cross calibration of each sensor data has to be examined. The radiometric properties of 3 kinds of composites are different from each other because of the differences of the scan geometry of the sun-ground-sensor.

2. SATELLITE/SENSORCHARACTERISTICS

2.1 NOAA/AVHRR

Table 1 shows the satellite/sensor characteristics of NOAA/AVHRR, ADEOS/OCTS and ADEOS-II/GLI. NOAA-9 and 11 are indicated as the examples.

NOAA satellite series has been operational since 1978 for weather monitoring after the missions of TIROS and ITOS series. It has been utilized for vegetation monitoring in large scale because of the worldwide coverage, the frequent observation and the capability of extracting NDVI (Normalized Difference Vegetation Index) since the global environmental problems arose.

In general, two NOAA satellites numbered with both an odd and an even number are operational at a time. The satellite withan odd, an even number crosses the equator in ascending mode in the afternoon, in the morning, respectively. The same area on the ground can be observed from 4 to 6 times in a day using the two satellites system. It was reported that the local time at descending node was delayed gradually (Kajiwara, et al., 1992). Furthermore, the rate of delay of local time became bigger year by year. The daily change rate of mean anomaly of NOAA satellite became faster. Consequently, the number of passes in one day became less and the recurrent period became bigger year by year. The daily change rate of mean anomaly of NOAA satellite became faster. Consequently, the number of passes in one day became less and the recurrent period became shorter. In case of NOAA -11, the local time at descending node was around 1:40 (corresponding to 13:40 in ascending mode) just after the launch in 1988, but the delay reached to 2.5 hours after 5 years, which resulted in the change of solar zenith angle even in the same seasons. Just after the launch, the recurrent period of NOAA-11 was about 10, which meant that the satellite passed through the almost same orbit after 10 days. After 5 years later, however, the period became about 8.

AVHRR is an optical mechanical radiometer with 2 bands in visible and near-infrared regions and 3 bands in thermal region with the spatial resolution of 1.1km at nadir. The FOV is ±55.4 degrees and the ground swath is about 3,000km.

2.2 ADEOS/OCTS

ADEOS will be launched in August 1996 by NASDA. One of the main objectives of this mission is to acquire data on worldwide environmental changes in order to contribute to international global environmental monitoring. To achieve the objects, some kinds of sensors such as optical sensors, microwave radiometers, scatterometers will be mounted. Among these sensors, OCTS will be expected to be used for vegetation monitoring in a large scale.

OCTS is an optical radiometer for the frequent global measurement of ocean color and sea surface temperature. It has 8 bands in visible and near-infrared regions and 4 bands in thermal region with the spatial resolution of 700m. The main target to be observed is the ocean, but the land areas will be also observed. The sensor gain will be changed whether the main target is the ocean or the land. The operational schedule for switching sensor gains is not determined as of the end of March in 1996.

OCTS adopts an optical mechanical system with a rotating mirror for achieving the wide FOV with ±40 degrees. 10 lines are scanned simultaneously in 1 swath. It covers about 1,400km on the ground and can observe the same area every 3 days. An unique characteristics of OCTS is to tilt a scan line along track by 20 degrees for avoiding a sungliter.

2.3 ADEOS-II/GLI

ADEOS-II is the successor to the ADEOS mission and planed to launch in early 1999. GLI among five sensors carried on ADEOS-II is the successor to OCTS. GLI is also an optical radiometer aiming at observing the reflected solar radiation from the earth's surface including land and ocean and the infrared radiation. It has 22 bands in visible and near-infrared regions, 5 bands in short-infrared region and 7 bands in thermal region. The spatial resolution is 1km at nadir, but some bands from visible to short-infrared regions has the resolution of 250m. It observes about 1,600km in width with the FOV of ±45 degrees. 12 lines are scanned at a time. The same areas are observed every 4 days. It has also the tilting function by 20 degrees.

3. METHOD OF COMPOSITE FOR NOAA/AVHRR(SUMMARY)

The author already proposed the method of image composite for vegetation monitoring using NOAA/ AVHRR (Hashimoto, et. al., 1992). The method is summarized as follows.

1) NDVI is sensitive to the solar zenith angle, especially in big angles (Singh,1988),(Matsumoto, et al.,1992). To weaken the effect of solar zenith angle on NDVI, the satellite data with odd number is primarily used because such a satellite on afternoon passes gives the lowest solar zenith angle in a day.
2) The marginal areas of an image with big scan angles are seriously distorted both geometrically and radiometrically. The central part of a line is primarily used to prevent large image distortions. The area of an image with the scan angle up to 30 degrees are preferable.
3) The NOAA satellite with an odd number revolved in about 9 days (strictly speaking, this period varies with satellite number and the elapsed time after launch). The shift of ascending nodes on adjacent two days in longitude is about 3 degrees (this value also varies with the elapsed time). The coverage width on the equator is about 26 degrees in longitude, corresponding to about 9 times of the daily orbital shift. So the period for a composite is set to 9 days.

4. COMPARISON OF THREE SENSORS WITH RESPECT TO SCAN GEOMETRY

The effects of the scan angle on the radiometric and geometric distortions on three kinds of sensor data are similar. So the scan angle up to 30 degrees is adaptable to every sensor data for the priority of use for image composite.

The period for image composite will be also supposed to be set as same as the case of AVHRR proposed in chapter 3, that will be 9 days. Figure 1 shows the relation of orbits and observed areas. The symbols 'o' and triangles indicate the orbit positions and the observed areas with the FOV of ±30 degrees. If the composite image covering the area in the equatorial regions observed on N-th day is prepared, the numbers of scenes acquired in nine days will be five, three and six for AVHRR, OCTS and GLI, respectively. The dates are as follows; N-2, N-1, N, N+1 and N+2nd for AVHRR, N-4, N and N+4th for OCTS, N-1, N, N+1, N+4, N+5 and N+6th for GLI. In the areas in higher latitude, off course, more scenes can be utilized for a nine days composite image. Figure 2 shows the variations of the scan angles at the same point which is located on the nadir on the equator and observed on N-th day. It is found out from these figures that some areas in the composite image of OCTS or GLI will catch only backward reflectance radiance and the others only forward ones. This property is very eminent for GLI. On the other hand, any point in the composite image of AVHRR will have the high probability to catch the radiance from various scan angles. In general, the backward and forward radiance from the same objects are different. The backward reflectance radiance from a dense forest is bigger than the forward one, while the case of a desert is vice versa.

When the period for image composite is set longer, for example almost one month (27 days), the composite image of AVHRR is usually produced using three sequential nine-days composite images. The method is adaptable for GLI. For OCTS, however, the image should be produced using fifteen scenes acquired on N-1, N-12, N+3, N-8, N+7, N-4, N+11, N, N-11, N+4, N-7, N+8, N-3, N+12 and N+1st days. In this case, the pixels on the composite image will be probably observed with various scan angles.

The solar zenith angle at observation affects NDVI. Figure 3 shows the coverage patterns and solar zenith angle of AVHRR and GLI at the vernal equinox. The case of OCTS is very similar to that of GLI. The gaps of GLI coverages can be identified in the regions of about 60 degrees in latitude owing to the tilt function. The patterns of solar zenith angle for AVHRR is changed even on the same season because of the delay of the local time at descending node. The characteristics of the solar zenith angle of composite image is as same as that of scan angle. Any pixel of AVHRR composite image has the probability to be observed with various solar zenith angles. While the pixels of OCTS or GLI are observed with some limited solar positions. If the monthly composite image is prepared by the method as mentioned before, various solar zenith angles will be identified on OCTS composite images.

5. METHOD OF IMAGE COMPOSITE

The method to make a composite image of OCTS and GLI as same as that of AVHRR proposed before is as follows;

1) The area of images with scan angle up to 30 degrees are primarily utilized.
2) The period for composite is set to 9 days. The numbers of images acquired during nine days are three for OCTS and six for GLI. Cloud free composite image will sometimes not be able to be produced, especially for OCTS because only three images are available during nine days. When the period is set to one month, three nine-day composite images of GLI are used to produce one month composite and fifteen images of OCTS indicated in chapter 4 (not nine day composite images) are used for one month.
3) The scan angle and the solar zenith angle of any pixel in the composite images of AVHRR, OCTS and GLI are different from each other. When those composite images are used integratedly for vegetation monitoring, cross calibration have to be examined with the considerations of these differences.

6. CONCLUSION

In this paper, the geometric properties of making the composite image of AVHRR, OCTS and GLI for vegetation monitoring are examined and the method of image composite is proposed. The OCTS and GLI data are not available. After the launch of ADEOS in this summer, I will examine to check the method using AVHRR and OCTS data.
If the method is adaptable, it willbe applied to GLI data in the future.

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Table 1 Characteristics of satellite／sensors

	NOAA-9／AVHRR	NOAA-11／AVHRR	ADEOS／OCTS	ADEOS−II／GLI
height (km)	850	850	797	802.9
period (min.)	102	102	101	101
inclination (deg.)	99	99	98.5	98.62
FOV (deg.) [swath]	±55.4 [3,000 km]	±55.4 [3,000 km]	±40 [1,400 km]	±45 [1,600 km]
IFOV (mrad) [spatial resolution]	0.944 [1.1km]	0.944 [1.1km]	0.85 [750m]	1.25 , 0.3125 [1km, 250m]
recurrency	≒ 14 + 1／8*)	≒ 14 + 1／9*)	14 + 11／41	14 + 1／4
lines per one scan	1	1	10	12
local time at descending node	approx. 2:20*)	approx. 1:40*)	10:30 ±15	10:30 ±15
spectral bands	vis - near IR (2) thermal IR (3)	vis - near IR (2) thermal IR (3)	vis - near IR (8) thermal IR (4)	vis - near IR (22) short IR (5) thermal IR (7)

*) The angular velocity of NOAA satellite is delayecd gradually. Consequently, the recurrency becomes less and the local time at descending node becomes later.

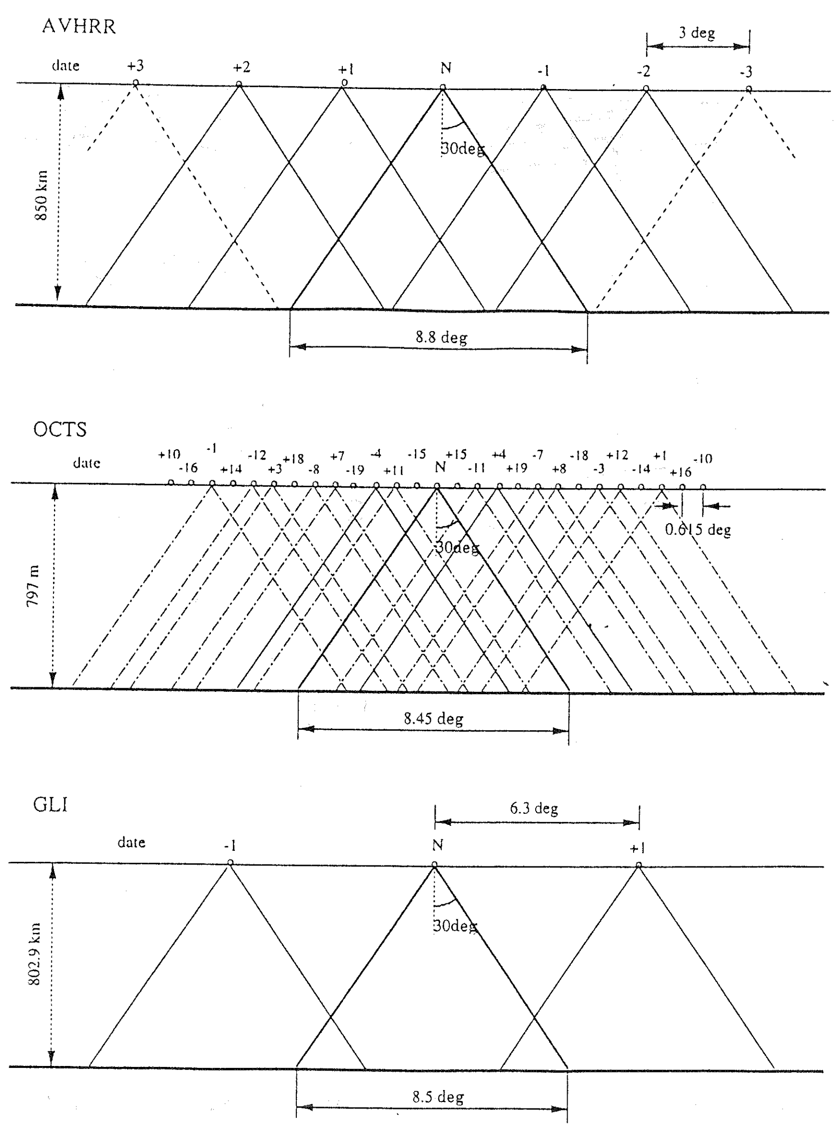

Figure 1 Consecutive orbit positioins and observed coverages (on the equator)

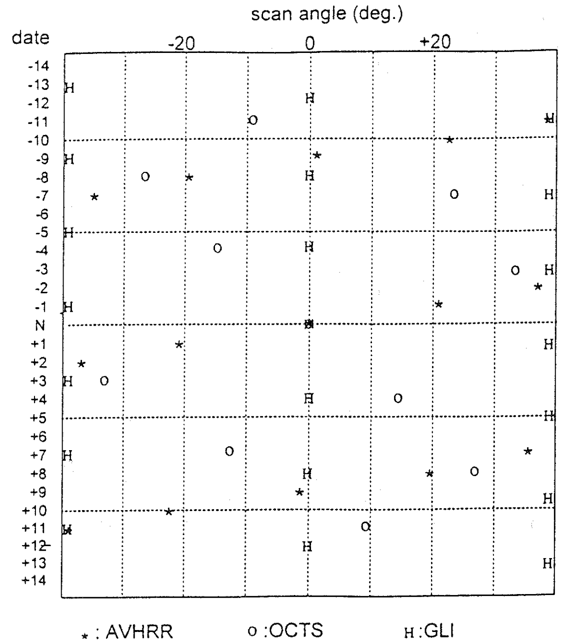

Figure 2 Variations of scan angles at nadir point which is obseved on N-th day

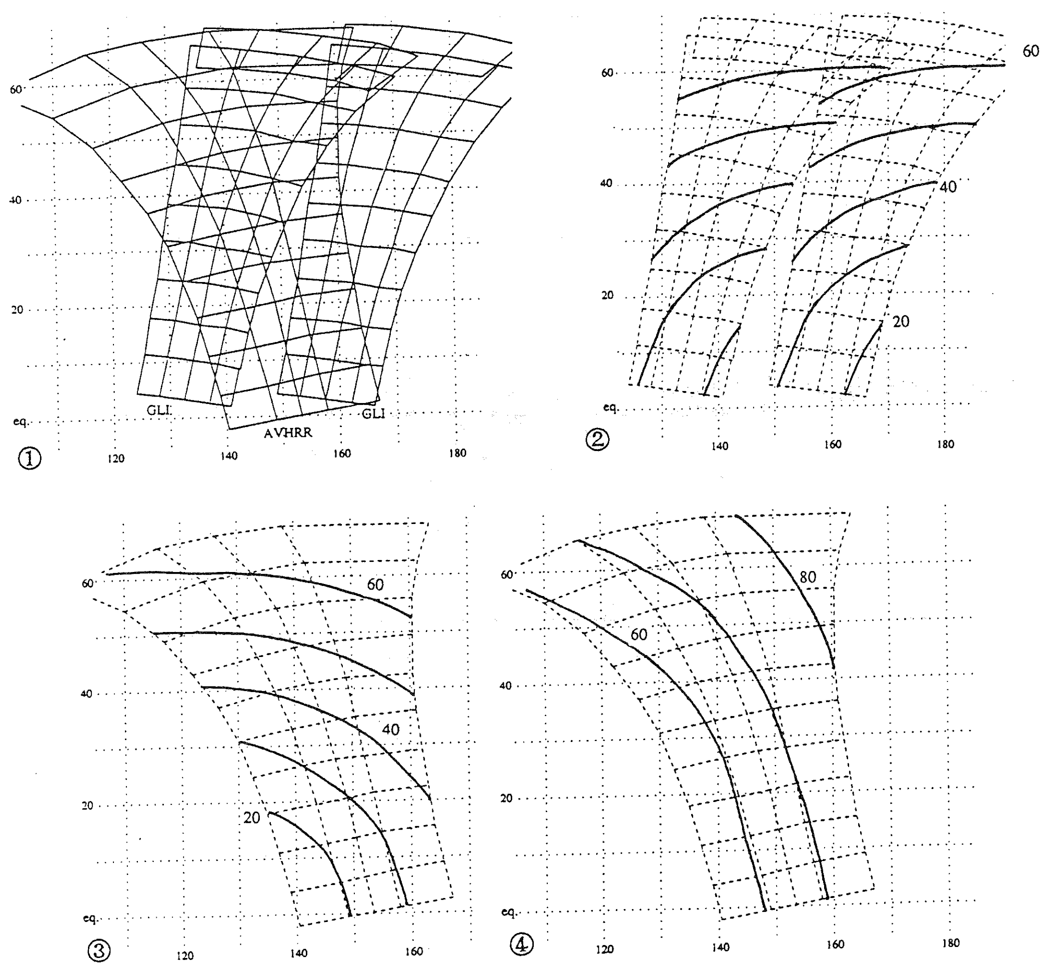

Figure 3 Patterns of coverage and solar zenith angle at vernal equinox of AVHRR and GLI
(1) coverage patterns of AVHRR and GLI
(2) solar zenith angle of GLI on consecutive 2 passes
(3) solar zenith angle of NOAA-11/AVHRR(March, 1989: after launch)
(4) solar zenith angle of NOAA-11/AVHRR(March, 1994)