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(E84-10035) [THEMATIC MAPPER RADIOMTRIC VARIABILITY ON OSTENSIBLY UNIFORM AGRICULTURAL SCENES] Quarterly Status and Technical Progress Report (State Univ. of New York) 7 p HC A02/MF A01 CSCL 05B G3/43

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In accordance with the requirements of GSFC Specification S-250-P1C (March 1972) I have pleasure in submitting the attached report.

The data coverage of Cass County (pass 30, row 27) requested for June, July, August and September 1983 has not been obtained from the Landsat Thematic Mapper due to satellite transmission problems. With the extensive and very cooperative help of Dr. John Lindsay of Systems and Applied Sciences Corp., further analysis has been performed on a previously obtained scene over the Webster-Fort Dodge area (path 27, row 31, 20th of September 1982) using the Goddard Space Flight Center analysis facilities.

This analysis has been helpful and illuminating for the reasons described below but has precluded any multitemporal analysis, since we are obliged by reason of satellite failure to work with only the one scene. The purpose of the investigation was to determine the radiometric variability on ostensibly uniform agricultural scenes. This was to determine the magnitudes of random and systematic radiometric errors which existed across the scenes in each of the thematic mapper bands, so permitting appropriate calibration for the systematic effects during preprocessing. A knowledge of random variations in radiometric signal from ostensibly uniform targets would permit estimation of likely discriminations which may be performed using either raw radiometric data or vegetation indices comprised of combinations of radiances in different thematic mapper bands.

Initial investigations were described in the last quarterly report and demonstrated a variation with scan angle in the radiance recorded for the scene described above. It was shown for this scene that there was an asymmetric variation of recorded radiance with scan angle, which depended upon the portion of the scene viewed. There was also a strong dependence upon bandpass.

Further work has been hampered by the failure of the array processor at the start of the last field trip to use the LAS at Goddard Space Flight Center.

Efforts have been made to analyze TM imagery by renting time on a local image analysis system. However, difficulties have been (unexpectedly) encountered in reading 6250 b.p.i. tapes (the format in which the image was provided.)

Studies on the LAS of a small region of considerable optical heterogeneity (Detroit airport) have suggested that in the time between successive overpasses, there have been apparent shifts in the spectral distribution of radiance from different (small) target areas. Since the overall radiance level on the two, sequential images is similar, it became apparent that resampling had possibly caused some relative changes to occur between images. Further thought suggested that the interaction of the sensor point spread function with the heterogeneous IFOV, consisting of different scene elements with different optical properties might have caused changes to occur in relative radiance distributions from ground targets between successive overpasses. Since multitemporal analysis requires that the change in spectral radiance with time be free from artifacts caused by the interaction of the sensor characteristics with the optical characteristics (scene element distribution in the IFOV, spectral reflectance bidirectional distribution of each element, relative area occupied by each element) it was considered appropriate to investigate the possible magnitude of the effects of such interactions for 'typical' scenes of selected type and heterogeneity.

To explain this point, a heterogeneous scene consists of reflecting (or emitting--depending on the bandpass used) elements whose distribution depends entirely upon the nature and condition of the scene. Data from a device which repetitively images a given scene (e.g. Landsat thematic mapper) with a repositioning accuracy of (say) 0.5 pixel will consist of radiance data recorded with a peaked PSF which is located over a selected part of the scene. Location of the IFOV center over a different geometrical distribution of scene elements by movement (i.e. between acquisitions) of the IFOV by a fraction of a pixel may cause a change in the absolute level of recorded radiance and in the spectral distribution of radiance between channels, since the sensor output in band r will be given by

$$L_r = \frac{\int_{\lambda_1}^{\lambda_2} I_r(\lambda).[\int_0^x \int_0^y \{a_1(x,y).P(x,y).R_1(\theta,\phi;\theta',\phi',\lambda) + a_2(x,y).P(x,y).R_2(\theta,\phi;\theta',\phi',\lambda) + \ldots + a_n(x,y).P(x,y).R_n(\theta,\phi;\theta',\phi',\lambda)\}\, dy.dx.E(\theta,\phi,\lambda).\tau(\theta',\phi',\lambda) + L_{path}(\theta_1,\phi_1;\theta'',\phi'',\lambda)]\, d\lambda}{\int_{\lambda_1}^{\lambda_2} I_r(\lambda).d\lambda} \qquad -(1$$

Where θ,ϕ are the zenith and azimuth angles of the sun and θ',ϕ' are the view zenith (scan) and azimuth angles of the sensor respectively (e.g.[1]). $I_r(\lambda)$ is the spectral response of the sensor in bandpass r. λ_1,λ_2 are the lower and upper (respectively) zero-power wavelengths of the sensor bandpass r, λ is wavelength, and $\tau(\theta',\phi',\lambda)$ is atmospheric transmission on the path to the sensor. $E(\theta,\phi,\lambda)$ is the global spectral irradiance at the target. $P(x,y)$ is the sensor response (governed by the PSF) at each point (x,y) within the IFOV and $a_n(x,y)$ is the fractional proportion of scene element n at point (x,y). Here we have considered the optical reflective case, and $R_n(\theta,\phi;\theta',\phi',\lambda)$

is the bidirectional spectral reflectance factor of scene element n (at point (x,y) in the IFOV).

Clearly, if the PSF is moved by a fraction of an IFOV, then the absolute radiometric response and the spectral distribution of recorded radiance may both be changed to an extent which depends upon the heterogeneity of the viewed area. In a multitemporal analysis, using artificial intelligence or, indeed using an automated approach of any kind, such changes could give spurious multitemporal signatures which may result in the misclassification and/or misquantification of targets. Such considerations will place tight requirements on the repositioning accuracy of data obtained repetitively. Further, radiometric modifications caused by resampling during processing will need to be carefully considered.

In order to place limits upon the size of this effect, studies are now underway on hypothetical interactions between TM PSF values in bands 1 and 4 with vegetative targets consisting of soybean areas which are subjected to stress of severe, medium and zero intensity. Using available line spread function (LSF) data[2], an approximate PSF has been calculated and plotted on a mylar template; this is moved incrementally, by 0.25 pixel (7.5 m) steps across a scene representative of regularly repetitive areas of soybeans, stressed to different levels of severity. Raw radiance and radiance ratio (TM4/TM1) data are plotted as a function of linear displacement. Already it is apparent that

- For repetitively spaced scene elements of sub-IFOV size, radiance values vary in a periodic fashion. The phase is different for different bandpasses. Both phase and periodicity will depend upon heterogeneity of deployment of scene elements and upon the optical properties of the scene elements.

- Ratioing two bands (in this case, TM4/TM1) can reduce the amplitude of the variation of the ratio with displacement.
- The amplitude of variation in radiance recorded in a given bandpass depends upon the areal distribution of scene elements with different optical properties.

This work will be reported at the TM meeting in December.

We have shown that the effects of the interaction of the sensor point spread function with a heterogeneous scene consisting of elements giving rise to different spectral radiant intensities will cause errors in multitemporal signatures due to fractional pixel repositioning errors. In the case of a heterogeneous scene, the re-positioning accuracy between acquisitions could affect the radiometric output in any band and could affect the spectral distribution of radiance between bands. Error caused by within-band and between-band variations in radiance with time could be compounded by resampling along and between scan lines during processing. The magnitude of both error sources will depend upon the degree of heterogeneity of the scene.

Clearly, much more work is needed in this area before any single-level or multi-level approach towards the acquisition and analysis of data from a smart sensor[3] to map and to monitor earth resources using multitemporal techniques and artificial intelligence with predictable accuracy may be attempted.

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