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Surface Texture Analysis with Thermal and Near Infrared Scanners

Fault lines, sea surface currents, and glacier crevasses may be detected.

Introduction

Texture analysis can be achieved by separating the frequency components, in contiguous bands, from a given scan signal. The signal modulation, for each contiguous frequency band, describes the variation or "texture" of the surveyed area with respect to points where the signal appears to be constant or "flat". For many different reasons the experience so far gained indicates that the best way to reach a satisfactory texture description consists in filtering, from the original video signal of a scanner, the highest frequencies corresponding to the geometrical resolution of the scanner itself and then in processing these components with a multi-stage logarithmic amplifier. On the other hand, although the natural phenomena would better be described by the high frequency components, the considerable increase in noise limits the readability of the results. To reduce such a source of misinterpretation, the video signal is limited by an adjustable threshold and then compressed by a double log-amplifier after the high frequency component separation (see Figure 1). The signals able to pass the threshold are then amplified by the log-amplifier in such a manner that the eye of the interpreter looks at the resulting picture and tries to correlate spots belonging to adjacent scan lines. We have to emphasize that the texture analysis performed by harmonic components extraction and by the introduction of threshold and log-amplifiers offers a qualitative approach to the interpretation. Nevertheless, the patterns enhanced by such a system appear to be of great help in making easier the job of the interpreter of remote sensing data.

Abstract: *Texture analysis applied to scannings collected in the domain of reflected and emitted infared radiance can be usefully employed for detecting glacial crevasses, and fault lines and for monitoring the current pattern at the sea's surface. Such an analysis, performed by high frequency extraction from scanning data followed by multistage logarithmic compression, enhances very subtle discontinuities existing at the surfaces in the field of reflection and emission. The contribution of the numerous phenomena involved can often be distinguished by the study of the correlation between the 1 to 2 μm and 9 to 11 μm channels. This method seems particularly useful in sensing the input of small volumes of water into the sea. It is useful for establishing a model for current circulation when bathymetric data are also used. While a number of appropriate methods have been developed for the mapping of faults, the thermal texture analysis method seems to be a promising tool for use in the study of glaciers, enabling the location of crevasses to be drawn on a map.*

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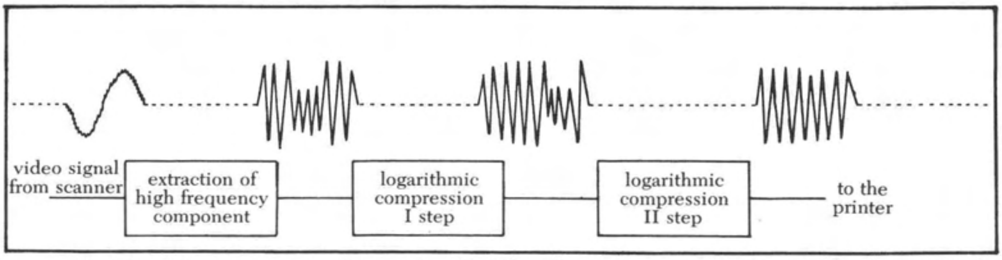


FIG. 1. Sketch of the precedure adopted for obtaining the texture analysis from video tape recorded scanning data. The original signal is filtered in order to separate the high frequency components, close to the maximum resolution of the device used. The components are compressed by a two-stage logarithmic amplifier and then printed on the photographic support. In many cases, after the frequency components separation, an adjustable threshold is introduced in such a manner that the double log-compression is not influenced by the high frequency noise.

TEXTURE ANALYSIS OF GROUND SURFACES

Texture analysis applied to thermal infrared data enhances variations due to the thermal inertia of outcropping materials, their moisture content, and the geometrical and physical discontinuities existing at the surface. Under the diurnal and seasonal solar load, different materials reach an actual instantaneous value of temperature which depends on mass density, heat capacity, and conductivity. In short, the temperature depends on the thermal inertia of the soil. Owing to the dependence of the emitted energy on the emissivity of the surface, the radiance gathered at the time of the survey will depend on both soil surface (emissivity) and sub-superficial properties (inertia). Thus, the texture described by the use of harmonic analysis in the thermal infrared domain will be able to enhance the presence of faulting systems through the phenomena induced at the surface (see Figure 2). Among the parameters influencing the surface heat emission and its discontinuities, we can mention moisture content, surface geometry (or, more commonly morphology), the presence of fractured material along fault lines, and the distribution of materials showing different thermal inertia. This is one of the different reasons for which we can find linears characterized by a positive or negative thermal anomaly. In the case of dry, fractured materials filling the faults, it would probably be found to be a positive anomaly, due to the faster heating of the fractured materials themselves, even if the flight had been performed late in the morning or at noon. On the contrary, a negative anomaly would appear if the fault is strongly moistened. Moreover, the underground circulation of fluids could considerably influence the sign of the thermal anomaly recognized along the linear feature. This last topic is a matter of geothermy.

In the short wavelength domain of the near infrared, texture analysis emphasizes the structural discontinuities of the surfaces. Superficial moisture on bare soil, the metabolic behavior of vegetation, and contacts with and geometry of outcropping formations, yield suitable data for discovering linear features in the spectral region of 1 to 2 μm. The fundamental difference occurring between the information and processing of data gathered in the near and thermal infrared domain is that the former is related to just the surface properties while the latter is also linked to sub-superficial phenomena. Thus, to obtain as much information as possible, the survey has to be carried out just before midday. At that time the solar reflected energy shows a good contrast and the energy emitted by the soil also shows good dynamics, since the thermal transitory is not yet completed.

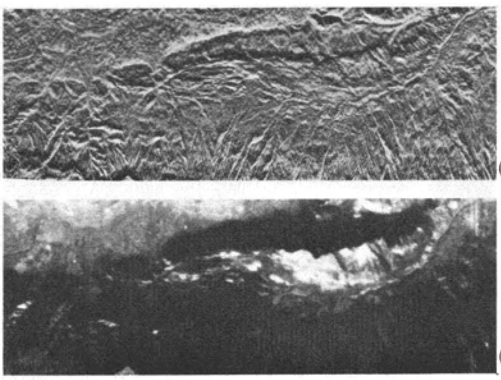

(a)
(b)

FIG. 2. Scanning taken in the 1 to 2 μm reflected infrared band, from an altitude of 3000 m over a mountain area (b) compared with the thermal texture analysis in 9 to 11 μm (a). The continuity of some linear features crossing the summit of the hill is easily recognizable. Some lines which can be observed in the lower part of the elaboration (a) are mainly due to the effect of weathering.

TEXTURE ANALYSIS OF WATER SURFACES

The pattern of surface thermal currents can be shown by the texture analysis of thermal infrared scannings performed over bodies of water. Due to the opacity to wavelengths longer than those of the visible spectrum, water shows in the thermal domain the phenomena occurring at its surface. Among these, the textural description of input flows such as sewage, rivers, pollutants, and fresh water springs, as well as of currents appears to be of particular interest (see Figures 3, 4, and 5). In many cases the phenomena to be investigated have to be approached from a dynamic point of view. Texture analysis enhances shape and the main direction of the superficial currents. By comparison with subsequent surveys carried out under different conditions of tide and wind velocity, a map of the intake's influence can be derived.

We can say that having at our disposal two subsequent thermal surveys, performed in opposite situations of wind and tide with the simultaneous use of the bathymetric data, the establishment of a three dimensional model for the currents seems to be possible. Such a model would allow the study of a given circulation cell and then the estimation of possible points of accumulation for pollutants and sediments transported by channels, rivers, etc. What we can observe through the thermal texture of a water surface is the "thermal roughness" related to the bottom morphology and then to the current pattern.

Texture analysis over water bodies is very effective for detecting very subtle intakes. For this purpose such a processing gives very useful additional information, since signal slicing is somewhat influenced by the noise.

At the shorter wavelenghts of near infrared, the signal collected over water bodies is very small and flat, due to the high absorption of the water itself. In this spectral domain the roughness corresponds to the surface geometry and a discontinuity has to be interpreted as an effect of a thin coating or film of chemicals or oil on the water surface. The non-homogeneous distribution of floating pollutants produces a modulation in the near infrared signals which, through texture analysis, emphasizes the presence of pollutants themselves.

One of the serious difficulties encountered in the processing of near infrared reflected energy from a water surface is the

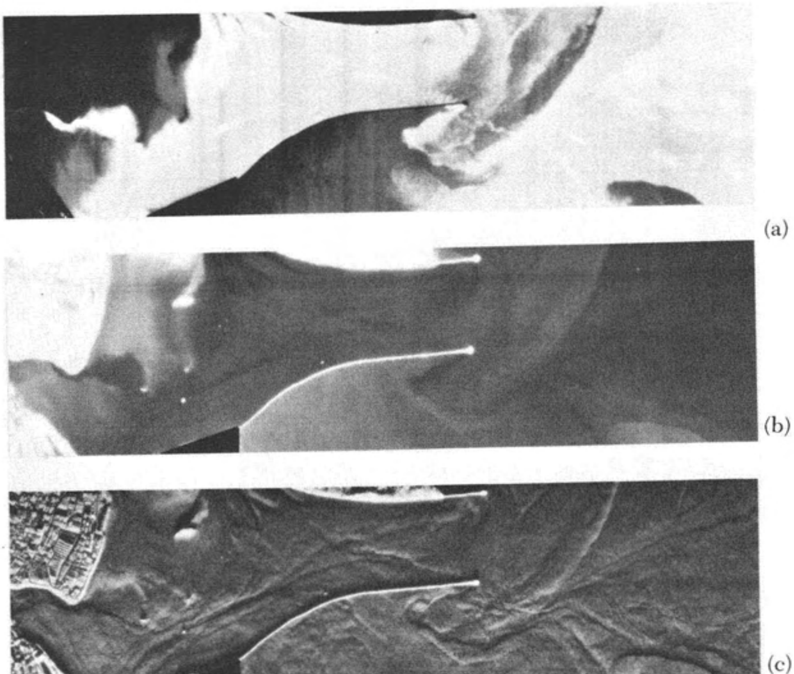


FIG. 3. Thermoscan of a water body in band 9 to 11 μm (b) compared with its level slicing (a) and with its texture analysis (c). The usefulness of the texture analysis is that it contours very subtle current patterns, allowing the interpreter to gather information on the circulation.

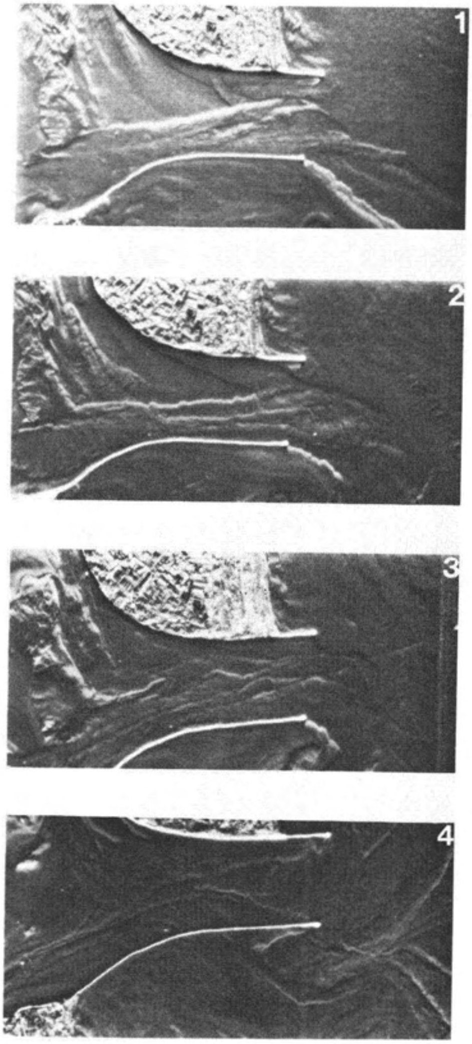


FIG. 4. With the help of subsequent thermal surveys the result of harmonic analysis becomes much more effective. Thermal texture of four passages made at one hour intervals is shown. The knowledge of bathymetric data, together with the distribution of velocity vectors, allows the prediction of sediment accumulation points.

fact that the reflection depends on the sun illumination angle. For this reason it is preferable to fly at a relatively high altitude, covering strips with a large amount of side overlap to minimize the influence of total reflection. The use of the "classical" bands of 3 to 5 μm and 9 to 11 μm allows the study of water reflection while also giving useful additional information on the emissivity characteristics of the floating chemicals. The difference between signals gathered within these spectral bands yields, on the sea water, the reflection at the shorter wavelength of 3 to 5 μm which doesn't show phenomena of total reflection. We can obtain the 3 to 5 μm reflection component as a consequence of the facts that the solar radiation is screened in the 9 to 11 μm band by 0_3 in the upper atmosphere and also that the emission of water, at least for a small temperature range, is proportional to the 3 to 5 μm and 9 to 11 μm bands. The difference can be approximated by the equations [N = Radiating Power]

$$N_{9-11} \simeq \xi_{9-11} N_{cn\ 9-11}$$

$$N_{3-5} = (1 - \xi_{3-5}) N_{s\ 3-5} + \xi_{3-5} N_{cn\ 3-5}$$

difference $D \simeq (1-\xi_{3-5})\, N_{s\ 3-5}$

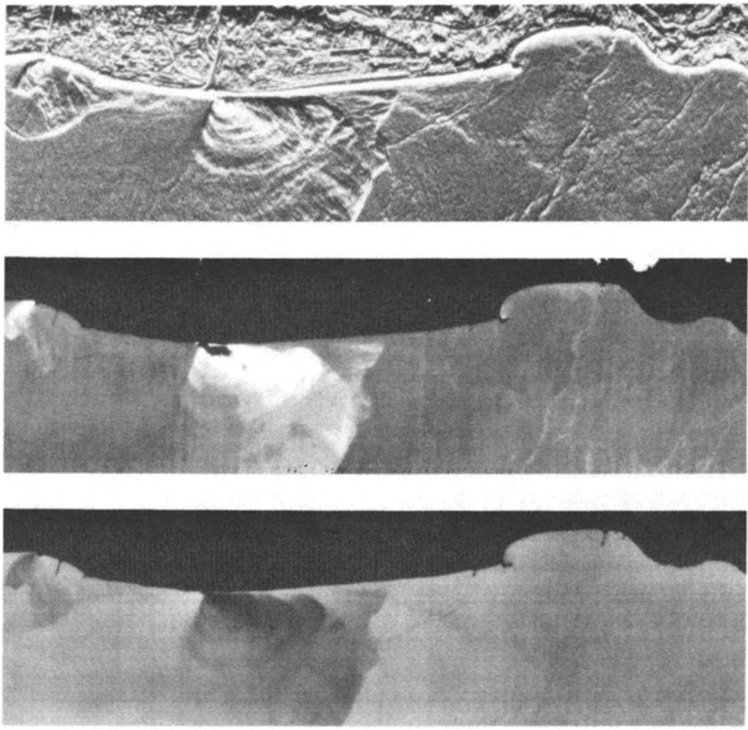
with the hypothesis being $N_{cn\ 9-11} = \alpha N_{cn\ 3-5}$ (with $\alpha = 1$) by calibration on reference emitting sources and $\xi_{3-5} \simeq 3_{9-11}$ on non-polluted sea surfaces.

This doesn't suffer from total sun reflection. Applying texture analysis to the difference instead of the original signals will describe the distribution of floating pollutants.

Texture Analysis of Glacier Surfaces

Near and thermal infrared scannings can both be used for the study of glacial surfaces. The signals show an unexpected but noticeable contrast in both the 1 to 2 μm and 9 to 11 μm bands, due to the structure of ice and snow and to their water content. Numerous experiments using the ground fixed thermovision system (AGA) show that temperature has little effect on emissivity. At the short wavelengths of near infrared, a fundamental role is played by the water content. This is able to produce a variation of 25 percent through the full dynamic range. In this spectral domain morphology constitutes a serious problem owing to shadows. Moreover, it has been observed that texture analysis applied to the near infrared band describes the accumulation of snow swept by the wind as a discontinuity. This leads to a misinterpretation with respect to the "force lines" and the existence of crevasses. Thus, it appears largely preferable to use the thermal band for texture analysis over glaciers, introducing the near infrared data as complementary information. Conversely, as far as snow melting is concerned, the near infrared band seems to be much more effective.

Mechanical stresses and discontinuities (crevasses) are produced at the surface of a glacier by the bottom morphology over which the glacier is moving. These discontinuities are very well enhanced by texture analysis (Figure 6). The force lines related to compression or release appear like cur-



(a)

(b)

(c)

FIG. 5. A strip of shoreline surveyed by thermal scanning (c) with a group of six isoradiant levels (b) and the corresponding texture (a). The flight was carried out for mapping the discharges into the sea and for computing their flow. The textural analysis is useful for monitoring the presence of very small intakes and for visualizing the current trends.

rent lines in a river. Crevasses tend to be generated where the bottom morphology of a glacier changes sharply, in the same way

(a)

(b)

FIG. 6. Negative of a themoscan taken over a glacier (b) and the corresponding texture obtained by the use of harmonic analysis (a). The negative performance of (b) has been chosen for better distinguishing some particulars of the snow cover. On the left side of the image (a) the effect of bottom morphology is clearly visible. A group of discontinuities forms an angle of $\pi/2$ with the "force lines." On the right side, the isotropic fracturing indicates the presence of a considerable amount of snow.

that a waterfall is formed in a river. Although a glacier is constantly shifting, crevasses are always generated in the same topographic position. Thus, a crevasse map drawn on thermal texture data is effective and useful in determining the crevasses absolute position.

The best period of year for carrying out the survey is the summer, when the presence of snow masking the ice stresses is minimal. Nevertheless, it is possible to obtain reliable information about crevasses even if covered by some snow, owing to the discontinuities appearing at the snow surface.

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