Noise Correction of Remote Sensing Imageries: Application to KOMPSAT/OSMI Data

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Abstract: The KOMPSAT/OSMI remote sending data of 800 km swath are collected by whisk broom method employing 96 charge coupled devices (CCDs). The stripping noises in the OSMI imageries, which arise mainly due to the non-uniform sensitivities of 96 CCDs, are the major hindrance for oceanographic applications of the OSMI data. The OSMI images are corrected by 'Ensemble Smoothness' method which is based on an assumption that the series of the averages and variances of digital numbers in each line should vary smoothly. The data of each line are corrected by linear regression model of which coefficients are obtained by Ensemble Smoothness method. Our algorithm can be applied not only to OSMI data but also for other remote sensing date collected by whisk broom or push broom.
Key words: OSMI, Ensemble Smoothness, Stripping Noise

1. Inroduction

The OSMI (Ocean Scanning Multi-spectral Imager) is one of the earth observation sensors installed on the Korea Multi-Purpose Satellite (KOMPSAT) launched in 1999. The primary mission of the OSMI sensor is to collect ocean color images. The OSMI image swath is 800km and spatial resolution is 850m. Six bands images in the spectral range of 0.4 to 0.9 μm are collected. The OSMI images are collected by whisk broom method using 96 charge coupled devices (CCDs). The OSMI imageries contain stripping noises, which is a serious hindrance for oceanographic applications of the OSMI data. The stripping noises arise mainly due to non-uniform sensitivities of 96 CCDs.

The stripping noises in the OSMI image can be corrected if 'true' values are known, but the true value are not available. The 'true' values should be guessed from the imagery data. The basic assumption applied in inferring the 'true' values are as follows. Each CCD element covers 1044 data along each line in the OSMI image. The average and variance of the digital numbers (DNs) of a line should have values close to those in the nearby lines. The smooth change of the mean and variance of DNs of each line is one of the fundamental properties of the nature, and we call that feature as 'Ensemble Smoothness'.

2. Ensemble Smoothness Model

(1) Linear regression model

Correction of DNs of j-th line by linear regression model is done by

$$y_{ij} = a_j x_{ij} + b_j \quad (1)$$

where x_{ij} is original DN of the pixel at column i and line j, and y_{ij} is the corrected DN of the corresponding pixel. The linear regression coefficients a_j and b_j are obtained by employing the ensemble smoothness property as follows.

The mean $\overline{x_j}$ and variance σ^2_{xj} of the DNs in the j-line pixels are obtained by

$$\overline{x_j}=\frac{1}{n}\sum_{i=1}^{n} x_{ij}\ ,\qquad \sigma^2_{xj}=\frac{1}{n-1}\sum_{i=1}^{n}(x_{ij}-\overline{x_j})^2 \tag{2}$$

where n is the number of pixels along a line (for case of OSMI, n is 1044). It can be shown that the mean $\overline{y_j}$ and variance σ^2_{yj} of the DNs in the j-th line transformed by the linear regression (1) can be expressed as

$$\overline{y_j}=\frac{1}{n}\sum_{i=1}^{n} y_{ij}=a_j\overline{x_j}+b_j,\qquad \sigma^2_{yj}=\frac{1}{n-1}\sum_{i=1}^{n}(y_{ij}-\overline{y_j})^2=a_j^2\,\sigma^2_{xj}\ . \tag{3}$$

The linear regression coefficients a_j and b_j of (1) can be obtained from (3) by

$$a_j=\frac{\sigma_{x_i}}{\sigma_{y_i}},\qquad b_j=\overline{y_j}-a\overline{x_j}\ , \tag{4}$$

provided the mean $\overline{y_j}$ and variance σ^2_{yj} of the 'true' DNs of the j-th line are known.

(2) Low-pass mean and variance

We assume the smooth low-pass digital filter series of the mean and variance as the 'true' or 'correct' values. The low-pass series of the 'correct' mean $\overline{y_j}$ is obtained by convolution of the original mean series $\overline{x_j}$ by

$$\overline{y_j}=\sum_{k=-M}^{M} f_k\,\overline{x_{j-k}} \tag{5}$$

where f_k is filter coefficient (convolution kernal) at spatial lag (or offsets in lines) k and M is the length of symmetric digital filter. The low-pass digital filter coefficients that permit passes of signal with period less than f_L are given by (Bennett 1979; Hamming, 1983)

$$f_0=2f_L\Delta t\ ,\qquad f_k=\frac{1}{\pi k}\sin(2\pi f_L\Delta t),k=1,2,....M \tag{6}$$

where Δt is sampling interval ($\Delta t=1$). In order to reduce wiggles (Gibbs' effect) in the frequency response function of the filtered series, Hamming window is multiplied to the filter coefficients. The same algorithm is applied in obtaining the 'correct' values of variances.

(3) Example demonstration

An example result of stripping noise correction by our ensemble smoothness method is shown below. Fig. 2 shows distributions of the mean $\overline{x_j}$ (the upper curve) and variance $(\sigma_{xj})^{1/2}$ (the lower curve) of 1824 lines of a single band (band 2) DN of OSMI image No. 4083 (2000, September 27). In this figure, the smooth curves are the spatial series of the low-pass means ($\overline{y_j}$) and low-pass variances $(\sigma_{yj})^{1/2}$. The OSMI band 2 image is shown in the lower part of the figure for comparison.

The image of each band is corrected separately. Fig. 3 shows the false color image of the combination of 3 bands (blue, green, red = band 2, 3, 4) of the original (left side image) and the corrected one (right side).

Discussion

More improved correction of stripping noise can be achieved by employing additional considerations as follows. The first improvement is done by correcting the image for land and sea parts separately, and later combine corrected images of land and sea areas. The land and sea parts in the image can be identified by the near infrared (NIR) band of OSMI data (OSMI band 8 data). A quadratic regression model is another candidate for an improvement of noise reduction. By combining linear regression models in the DN ranges of lower and higher parts, we can construct a quadratic regression model for image correction of each line.

Our ensemble smoothness method yields substantial noise correction of the OSMI imageries. Our method can be successfully applied for noise corrections of other remote sensing imageries, such as MODIS and ASTER, of which data are collected by push broom or whisk broom.

References

[1] Bennett, R. J. 1979. *Spatial Time Series*, Pion Limited, London, 674 pp.

[2] Hamming, R.W. 1983. *Digital Filters*, 2nd Ed., Prentice-Hall, 257 pp.

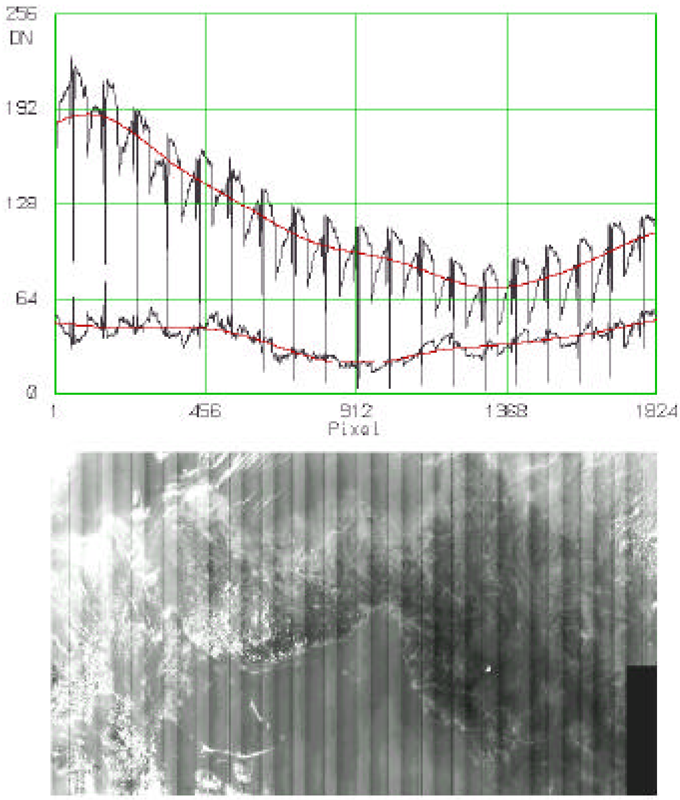

Fig. 1. Mean (the upper curve) and variance (the lower curve) of DN of each line (OSMI No. 4083, Band 2 image). Smooth curve is the low-pass series. The original image is shown in lower part for comparison.

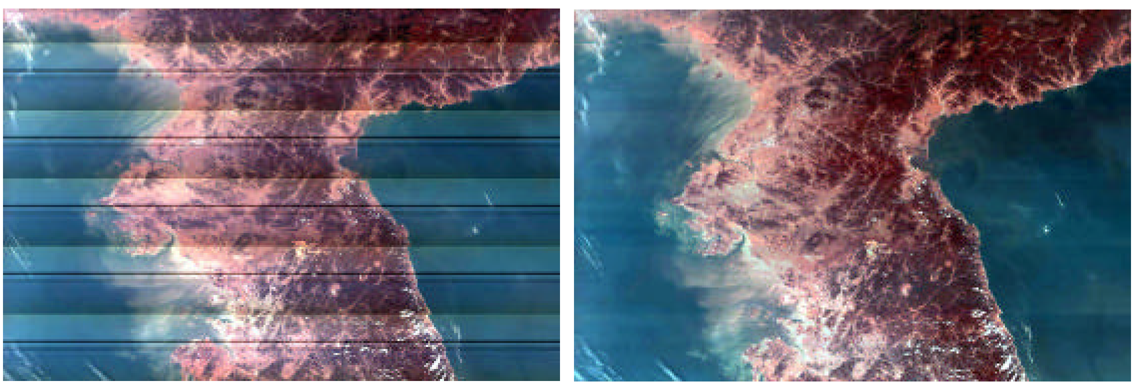

Fig. 2. The original (the left part) and corrected (the right part) images of OSMI data No.4083. False color images are made by blue (Ch .2), green (Ch. 3) and red (Ch. 4).