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Evaluation of Atmospherically Gases Using Models FLAASH and QUAC to Hyper-spectral imagery

Abstract

The important step is correction of the effect of atmospheric on hyper-spectral imagery of the VIS “visible”, short wave & NIR “near-infrared” spectral range. In general, the cause for limiting the use of hyperspectral images is the atmospheric effects, so, atmospheric correction is necessary for any accurate processing. In this work, two atmospheric correction techniques have been applied on Hyper-spectral image. From the raw original image and also from the FLAASH and QUAC atmospheric corrected images the spectra of vegetation, water and soil were extracted. The acquisition data for study contained Hyperion bands for year “2015” images over each of the following regions: first region is the sedimentary plain in the central region of Republic of Iraq and the second region is a mountainous area of the northern regions of the Republic of Iraq. The survey will focus mainly on the precision of the atmospheric compensation algorithms by comparing the corrected bands location in the reflectance measurement of different surface types collected for each region. The results of two algorithms in the mountainous area that have terrain are best than the sedimentary plain area.

Keywords

Hyperion, FLAASH, QUAC, Atmospheric attenuation.

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1. Introduction

Imaging spectrum analysis has important applications in several fields. It constitutes a new method for remote sensing on earth, and it is now technically possible and can be implemented from aircraft and spacecraft. Remote sensing of earth surface from aircraft and spacecraft provides information and data not readily acquired via surface observations. The begging of imaging spectrum analysis, or hyper-spectral imaging of the earth surface is constructed at the NASA Jet Propulsion Laboratory (JPL) [1–3]. The vision of the surface of earth from aircraft and spacecraft are degenerated because of the atmosphere. The term “degraded” means attenuation of reflected light and lack of contrast because of sunlight dispersion through atmospheric aerosols and molecules. Removal of atmospheric effects was referred to as atmospheric correction [4]. There are numerous algorithms of atmospheric correction like FLAASH (Fast Line of sight Atmospheric Analysis of Spectral Hypercubes) technique, Empirical line technique, QUAC (Quick Atmospherically Correction) and several other algorithms. In this paper, the effects of atmospheric components in the FLAASH and QUAC algorithms for Hyperspectral image of Hyperion satellite were studied, and the algorithms of FLAASH and QUAC, two qualitative and quantitative spectral analyses on Hyperion image were implemented and compared. The reflectance measurements field were obtained from known sites through visiting the study areas, where samples were taken from vegetation, soil, and water and examined at the same time with an Analytical Spectral Device (ASD) spectroradiometer to implement the spectral quality analysis of the models. Results showed that the FLAASH method achieved the best results for decreasing some of the atmospherically effects; however, QUAC method caused vigorous anomalies in the corrected reflectance. The main process of this study involved three steps as follows:

- FLAASH algorithm application
- QUAC algorithm application
- Comparing the results between two algorithms

2. Study area and used data

In this study, two distinct regions were selected in terms of terrain: the first region was the sedimentary

plain of the central part of the Republic of Iraq, whereas the second region was the mountainous area of the northern part of the Republic of Iraq. The aim of this research was to distinguish and compare between FLAASH and QUAC techniques by using the topography of the two selected areas. The first study region is located between a longitude $44^{\circ}10'15.24$ east and latitude $33^{\circ}12'56.96$ of Baghdad province in Iraq (Fig. 1). The region also has no mountainous terrain since the area is a sedimentary plain. The test images were obtained via the EO1 satellite on 12 November 2015 at Scene Start Time 06:15:40.036 and Scene Stop Time 06:15:54.036.

The second study area is located between “a longitude of $44^{\circ}14'29.09$ east” and latitude $35^{\circ}27'03.80$ north” in Northern governorates in Iraq (Fig. 2). The test images were obtained via the EO1 satellite on 28 November 2015 at Scene Start Time 06:03:08.684 and Scene Stop Time 06:03:27.684.

The Hyperion device collected an aggregate of (242) channels from (356–2577) nanometer. At in about a (10) nanometer spectral resolution with (30) meter spatial resolution. All sensors included single panchromatic band at (10) meter spatial resolution and nine multispectral bands at (30) meter spatial resolution, converging wavelengths ranging from (433–2350) nanometer [5].

3. Methodology

3.1. Atmospheric correction

Numerous atmospherically correction algorithms have been tested, such as: Dark Object Subtraction, Quick Atmospheric Correction, Fast Line-of-sight Atmospheric Analysis of Hypercube (FLAASH), Empirical Line method as well as other algorithms [6]. In this work, two methods of Atmospheric correction were studied: FLAASH and QUAC Atmospheric Corrections.

3.2. FLAASH atmospheric correction

FLAASH is the first principle atmospheric correction tool to correct wavelengths in the VIS through NRI and SW regions. It works up to $3\text{ }\mu\text{m}$, with extreme hyperspectral and multispectral sensors. FLAASH works in the (0.4–2.5) μm spectral range. As an initial step, MODTRAN4 simulations of spectral

Fig. 1. (a) Administrative map of Iraq showing the international and local borders between the provinces. The study area longitude of Baghdad province 44°10'15.24 east and latitude 33°12'56.96 north in Baghdad province. (b) Photomap of the first study area using hyper spectral Image.

radiance are perfected for many atmospheric, water vapor and viewing conditions (solar angle) over the range of reflectance's of surface to prove the lookup tables for the atmospheric parameters of water vapor, aerosol type and visibility for the later use [7]. FLAASH tools up the graphical user interface for the MODTRAN4 spectral calculations, containing data simulation. Essentially, it is developed from a standard equation for spectral radiance at a sensor pixel (Equation (1)) [8]:

$$L^* = \frac{A\rho + B\rho_e}{1 - \rho_e S} + L_a^* \quad (1)$$

where:-

- (L^*): represents spectral radiance at the sensor pixel
- (ρ): represents the pixel surface reflectance
- (ρ_e): is the average surface reflectance for the pixel and the surrounding region
- (S): is spherical albedo of the atmosphere (capturing the backscattered surface-reflected photons)
- (A and B): are coefficients that vary according to the atmospheric and geometric conditions but not the surface condition

Fig. 2. (a) Administrative map of Iraq showing the international and local borders between the Northern governorates. The study area longitude of 44°14'29.09 east and latitude 35°27'03.80 north Northern provinces in Iraq. (b) Photomap of the second study area using hyper spectral Image.

- (L^*a): is the radiance backscattered by the atmosphere

Equation (1): The first expression is equal to the radiance reaching the surface (from each sky-shine and direct solar illumination) which is backscattered direct into the sensor, whereas the second expression equals to the radiance from the surface that is re-scattered via the atmosphere to the sensor. The values of A, B, S and L_a are fixed from MODTRAN4 calculations that employ the viewing and solar angles and mean surface elevation of the measurement, and they assume a certain model atmosphere, aerosol type and visible range. So, all the variables in equation (1) were implicitly wavelength dependent [9–11]. The algorithm of FLAASH was illustrated as follows:

3.3. QUAC atmospheric correction

QUAC was developed by Spectral Sciences Inc. and it is available in ENVI. It does not require a prior knowledge of atmospheric conditions because atmospheric correction parameters are determined directly from the observed pixel spectra in a scene. QUAC is efficient in terms of processing time, and another advantage of QUAC is that it works on all image sensors even if the sensor does not have proper calibration of data. The disadvantage of QUAC is that it is not as accurate as other atmospheric corrections. It is an empirical algorithm based on a squeeze of preset and default parameters. The default setting supplies

very good corrections for the large majority of data cubes. However, problematic cubes are sometimes experienced [12,13]. The basically physics of atmospheric correction is depicted in (Fig. 3). The noticed spectral radiance, L_{obs} for pixel with surface reflectance, ρ_{sur} is the total sum of three paths shown by Ref. [14].

$$L_{obs} = (A + C\rho_{ave}) + B\rho_{sur} \quad (2)$$

The components in $(A + C\rho_{ave})$ were grouped with each other because they resort to be approximately constant on an image, therefore, they could be treated as an offset common to all the image pixel. These simple linear relations could be rearranged to express the restored surface reflectance in terms of the observed signal and derived atmospheric parameters. Together, because they resort to be approximately constant over an image, thus could be considered as an offset common to all the image pixels. This simple linear relationship could be rearranged to express the restored surface reflectance in terms of the observed signal and derived atmospheric parameters.

$$\rho_{sur} = Gain (L_{obs} - Offset) \quad (3)$$

where: $Gain = 1/B$, and $Offset = (A + C\rho_{ave})$. For a physics based approach A, B, and C are restored through comparison of spectral features to those forestalled by radiative transfer calculations. For QUAC, these parameters are resolved directly from the in-scene

Fig. 3. Shows three types of paths A, B and C that solar photons can move on their way to remotely lying observer, where ρ_{sur} is the fundamental reflectance of the observe surface pixel, ρ_{ave} refers to the spatially-averaged reflectance of the surrounding pixel, and L_{obs} is the at-sensor radiance corresponding to the observed surface pixel.

spectral information and the key underlying assumption.

The algorithm of QUAC is illustrated as follows:

4. Results and discussion

In this research, hyper-spectral remote sensing data was used for Hyperion satellite of type (EO1H1690372015316110KF -1R). All the bands were not used for the image, the bad bands were neglected and only bands containing information were used. It is in VNIR 8–57, SW 77–120, 133–164 and 193–219. Three different areas were identified and processed in the software ENVI by region of interest (ROI) and FLAASH and QUAC atmospheric correction methods were applied as shown in (Fig. 4):

4.1. Results of FLAASH method

The FLAASH technique was applied to a hyper-spectral image, and the results for the first study land covered (water, vegetation, soil) and illustrated as follows:

To study the removal of atmospheric effects on image clarity after application of atmospheric correction techniques, the histogram of images was plotted before correction and calibration and after the application of FLAASH algorithms (see Fig. 5). In Fig. 6, the first column represents the histogram and ROI area of study for the original image which observed the ranging of histogram between 0 and 200 range as well as the high noise because of the atmospheric effects.

The second column represents the histogram and ROI areas of study for image calibration which observed the range of histogram between 0 and 250, and the third column represents the histogram and ROI areas of study for image corrected by FLAASH technique which observed the range of histogram between 0 and 230.

The clarity of the images in column (b, c) is better because of the removal of the atmospheric effects.

In general, the peak spectra absorption before atmospheric correction was shown in Fig. 7(a) at (721.9, 762.9, 823.65, 902.36, 935.58, 942.73, 1144.48, 1386.65, 1684.9, 1820.48, 2052.45 and 2314.81) nm. Next, after applying atmospheric corrections on hyperspectral remote sensing information using FLAASH correction was shown in Fig. 7(b) peak absorption at (447.17, 894.88, 942.73, 1043.59, 1245.36, 1558.12, 2163.42, 2203.83 and 2314.81) nm.

FLAASH atmospherically correction methods are shown in Fig. 6 for ROI (water, vegetation and soil) land cover. Fig. 8-a represents the spectral profile measured by an ASD device, and this spectral profile is free of atmospheric effects. In the range of wavelength (426–1400) nm, there was a very strong correction, because weak atmospheric attenuation for ROI area of the study, while the range (1336–1490) nm had highly strong atmospherically attenuation, because of water vapor. It is not possible to correct these regions, also in the range (1790–1971) nm, there was a very strong atmospheric attenuation, atmospheric components of gases and water vapor and hence the presence of the zeroed-out bands in the corrected data as shown in Fig. (8).

Fig. 10 (a, b) Shows the spectral profile before and after FLAASH correction to the second study area.

FLAASH corrected spectral to land-cover water in the range (1900–2500) nanometer wavelengths marker over rating of water vapor absorption. The soil and vegetation spectral of FLAASH diagnostic dips at (550–580) nanometer which matches to the presence of chlorophyll-b in the healthful leaves. The absorption of cellulose at (2180) nanometer in spectral is derived from FLAASH model diagnostics. The presence of protein and nitrogen causes dips of absorption in the leaves seen at (2032–2100) nanometer as shown in Fig. (11) (see Fig. 12).

5. Results of QUAC method

The QUAC technique was applied to a hyper-spectral image, and the results were illustrated as follows:

Fig. 4. The image of a hyper-spectral image of the first study area. The region inside the red squares has been processed with QUAC, and FLAASH. (a) The first region was selected and processed including water, (b) the second region was selected and processed including vegetation, and (c) the third region was selected and processed including soil.

Fig. 5. The image of hyperspectral image of second steady area. The region inside the red squares has been processed with QUAC and FLAASH methods. (a) The first region was selected and processed including water, (b) the second region was selected and processed including vegetation, and (c) the third region was selected and processed including soil.

Fig. 6. ROI image and Histogram (a) Original image, (b) Radiance image, (c) FLAASH corrected image.

Fig. 7. (a) Spectral profile of original, (b) Spectral profile of FLAASH.

Fig. 8. Spectral profile of ROI land cover (water, vegetation and soil) (a) ASD spectral without distortion, (b) Image spectral with distortion, (c) Spectral of FLAASH correction. The results of model arithmetical FLAASH of atmospheric correction that were applied in the second study area are shown in Fig. (9).

Fig. 13 (a) Shows the peak spectral absorption before atmospheric correction, when applying QUAC technique, the top absorption spectral at (487.87, 538.83, 942.73, 1104.19, 1144.48, 1346.25, 1467.33, 1769.99, 1991.96, 2042.45, 2113.04, 2163.43, 2203.83, 2314.81 and 2385.4) nm as shown in Fig. 13(b).

Fig. 14 shows the result of QUAC atmospherically correction methods for the land–cover (water, vegetation and soil). Corrected spectra in the range 426–1300 nm wavelengths indicated a weak atmospheric attenuation for ROI area of the study, but no correction in the range (1400–1499) nm and (1800–1999) nm because of the very strong atmospheric attenuation due to water vapor and CO₂.

Fig. 15 shows the results of QUAC correction to the second study area.

Fig. 16 shows the spectral profile before and after correction by QUAC. The dips after correction in the (900, 1500, 1550 and 2000) nm are observed.

In the range 1500–1780 nm wavelengths, QUAC to water land cover indicated rating of water vapor absorption. For spectral vegetation and soil, QUAC diagnostic very narrow peaks at 900 nm wavelength indicating the absence of chlorophyll-b in unhealthy leaves. QUAC show dips at 444 and 721 nm for vegetation and soil spectra which corresponds to the presence of chlorophyll-b in the healthful leaves. The absorption dips at (2320) nm of spectral derived from QUAC model because of the presence of cellulose, while the absorption in diagnostic is also seen at (2022 and 2032) nm, which corresponds to the presence of protein and nitrogen in the leaves as shown in Fig. (17).

Fig. 9. ROI image and histogram (a) Original image, (b) Radiance image, (c) FLAASH corrected image.

Fig. 10. (a) Spectral profile of original, (b) Spectral profile of FLAASH.

The comparison between the two techniques for the first study area demonstrated that the cut-off area indicated the presence of water vapor, nitrogen gas and oxygen gas, therefore, it was noted that there is a high

atmospheric effect in the region between 900 nm and 1000 nm and between 1200 nm and 1500 nm. By comparing the results, we have found that FLAASH technique is better than QUAC technique in flat areas.

Fig. 11. Spectral profile of ROI land cover (water, vegetation and soil) (a) ASD spectral without distortion, (b) Image spectral with distortion, (c) Spectral of FLAASH correction.

Fig. 12. ROI image and histogram (a) Original image, (b) Radiance image, (c) QUAC corrected image.

Fig. 13. (a) Spectral profile of original, (b) Spectral profile of QUAC.

Fig. 14. Spectral profile of ROI land cover (water, vegetation and soil) (a) ASD spectral without distortion, (b) image spectral with distortion, (c) spectral of QUAC correction.

6. Conclusions

The first step in atmospheric correction is important to enhance symmetry of spectral signing up of the region of different interests. We adapted the FLAASH and QUAC technique to strip the effect of gases absorption and water vapor in the air. Water spectra were compared to QUAC and FLAASH with each other and the results indicated that spectra of both images showed a similarity in the absorption features.

Vigorous absorption at (515, 691, and 1477) nanometer is due to high percentage of water vapor and oxygen gas in the area, and weak absorption at (845 and 1200) nanometer is due to the percentage of ozone gas and other atmospheric components. Spectra vegetation of QUAC and FLAASH were comparable in both results indicating that the spectra of both images showed similarity in the absorption features. Strong absorption in the (520 and 770) nanometer is due to the pigment in vegetation. Weak absorption in the (931 and 1114)

Fig. 15. ROI image and histogram (a) Original image, (b) Radiance image, (c) QUAC corrected image.

Fig. 16. (a) Spectral profile of original, (b) Spectral profile of QUAC.

nanometer is due to the presence of water in leaves. Strong absorption at (1477 and 2000) nanometer in all spectra is due to the presence of water in the vegetation.

The soil spectra of QUAC and FLAASH were compared with each other and the results indicated that the spectra of both images showed a similarity in the absorption features. Strong absorption at (905 and

1265) nanometer is due to high percentage of water vapor. Weak absorption at (942 and 1134) nanometer is also due the high percentage of water vapor. The spectral signatures of different ROI areas from study exposures showed better results of FLAASH model compared to QUAC model correction. The spectra are well recompensed for impact of the gases and water vapor.

Fig. 17. Spectral profile of ROI land cover (water, vegetation, and soil) (a) ASD spectral without distortion, (b) Image spectral with distortion, (c) Spectral of QUAC correction.

References

- [1] B. Gao, M. Montes, Z. Ahmad, C. Davis, Atmospheric correction algorithm for hyperspectral remote sensing of ocean color from space, *Appl. Optic.* 39 (2000) 887–896.
- [2] A. Goetz, G. Vane, J. Solomon, R. Barrett, Imaging spectrometry for earth remote sensing, *Science* 228 (1985) 1147–1153.
- [3] B. Gao, M. Montes, C. Davis, A. Goetz, Atmospheric correction algorithms for hyperspectral remote sensing data of land and ocean, *Remote Sens. Environ.* 113 (2009) 17–24.
- [4] L. Bernstein, X. Jin, B. Gregor, S. Adler-Golden, Quick atmospheric correction code: algorithm description and recent upgrades, *Opt. Eng.* 51 (2012).
- [5] M. Cetin, N. Musaoglu, Merging hyperspectral and panchromatic image data: qualitative and quantitative analysis, *Int. J. Remote Sens.* 30 (2009) 1779–1804.
- [6] N. Bernardo, F. Watanabe, T. Rodrigues, E. Alcantara, Atmospheric correction issues for retrieving total suspended matter concentrations in inland waters using OLI/Landsat-8 image, *Adv. Space Res.* 59 (2017) 2335–2348.
- [7] F. Kruse, Comparison of ATREM, ACORN, and FLAASH atmospheric corrections using low-altitude AVIRIS data of Boulder, CO, in: *Proceedings of the 13th JPL Airborne Geoscience Workshop*, Jet Propulsion Lab, Pasadena, CA, 2004.
- [8] H. Nguyen, J. Jung, J. Lee, S.U. Choi, S.Y. Hong, J. Heo, Optimal atmospheric correction for above-ground forest biomass estimation with the ETM+ remote sensor, *Sensors* 15 (2015) 18865–18886.
- [9] A. Berk, S. Adler-Golden, A. Ratkowski, G. Felde, G. Anderson, M. Hoke, T. Cooley, J. Chetwynd, J. Gardner, M. Matthew, L. Bernstein, P. Acharya, D. Miller, P. Lewis, Exploiting MODTRAN radiation transport for atmospheric correction: the FLAASH algorithm, in: *Proceedings of the 5th International Conference on Information Fusion (FUSION) vol. 2*, 2002, pp. 798–803.
- [10] X. Zhang, H. Yang, T. Shuai, Comparison of FLAASH versus Empirical Line approach for atmospheric correction of OMIS-II imagery, *Bull. Surv. Mapp.* 8 (2010).
- [11] S. Sultan, W. abbas, A. Ali, A review on arithmetic modules to removing effects of atmosphere, *Indian J. Natl. Sci.* 9 (2018) 15741–15758.
- [12] S. Carr, L. Bernstein, S. Adler-Golden, The quick atmospheric correction (QUAC) algorithm for hyperspectral image processing: extending QUAC to a coastal scene, in: *Proceedings of the International Conference on Digital Image Computing: Techniques and Applications (DICTA)*, Adelaide, Australia, 2015, pp. 1–8.
- [13] L. Bernstein, S. Adler-Golden, X. Jin, B. Gregor, R. Sundberg, Quick atmospheric correction (QUAC) code for VNIR-SWIR spectral imagery: algorithm details, in: *Proceedings of the 4th Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS)*, 2012, pp. 1–4.
- [14] S. Lawrence, M. Steven, X. Jin, B. Gregor, R.L. Sundberg, Quick atmospheric correction (QUAC) code for VNIR-SWIR spectral imagery: algorithm details, *Opt. Eng.* 51 (2012).