DigitalGlobe™
1900 Pike Road
Longmont, Colorado, USA, 80501

Radiance Conversion of QuickBird Data

Technical Note

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Prepared by: Keith Krause
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This tech note discusses the conversion from a corrected counts QuickBird product to top-of-atmosphere spectral radiance. QuickBird products are delivered to the customer as radiometrically corrected image pixels ($q_{Pixel,Band}$). Radiometric correction includes a dark offset subtraction and a non-uniformity correction (detector-to-detector relative gain). Corrected counts are specific to the QuickBird instrument and therefore QuickBird imagery MUST be converted to spectral radiance before radiometric/spectral analysis or comparison with imagery from other sensors in a radiometric/spectral manner. The information contained in this tech note applies to all QuickBird imagery products EXCEPT pan-sharpened products.

1 Conversion to Top-of-Atmosphere Spectral Radiance

Conversion to top-of-atmosphere spectral radiance is a simple two step process that involves multiplying radiometrically corrected image pixels by the appropriate absolute radiometric calibration factor (also referred to as a K factor) to get band-integrated radiance [$W\text{-}m^{-2}\text{-}sr^{-1}$] and then dividing the result by the appropriate effective bandwidth to get spectral radiance [$W\text{-}m^{-2}\text{-}sr^{-1}\text{-}\mu m^{-1}$]. Based on ground truth measurements and confirmed by analysis from the Joint Agency Commercial Imagery Evaluation (JACIE) Team, the QuickBird absolute radiometric calibration factors (K factors) were revised. The "revised" values are based on pre-flight estimates and should be applied to all QuickBird imagery acquired from launch up through the present date. The revised absolute radiometric calibration factors (K factors) were operationally released in the production system on June 6, 2003 at 0:00 GMT.

Absolute radiometric calibration factors (K factors) are delivered with every QuickBird product and are located in the image metadata files (extension .IMD). Products generated after June 6, 2003 at 0:00 GMT have the revised factors in the .IMD files. These values should be used to convert to band-integrated radiance or spectral radiance. However, products generated before June 6, 2003 at 0:00 GMT have been delivered with the original calibration factors. For better results, conversions to band-integrated radiance or spectral radiance should be performed using the factors listed in the tables in this tech note, instead of those delivered in the .IMD files. The next section contains a description of the proper way to convert to band-integrated radiance for both 16-bit and 8-bit products generated both before and after the revised factors were operationally released. NOTE: conversion equations are to be performed on all pixels in a given band of a QuickBird image and should use 32-bit floating point calculations. At the option of the customer, the resulting floating point values of band-integrated radiance or spectral radiance may be rescaled into a desired 16-bit or 8-bit range of brightness as may be required for handling by an image processing system. When doing this, it is recommended that the customer keep track of subsequent conversions so that there is a known relationship between any new image DNs and the band-integrated radiance or spectral radiance of the pixel for the given band.

1.1 Band-Integrated Radiance [$W\text{-}m^{-2}\text{-}sr^{-1}$]

The proper way to convert QuickBird products from radiometrically corrected image pixel values to band-integrated radiance depends on the generation time and the bit depth of the product. These values are contained in the .IMD files. Generation time uses the UTC time format and in the .IMD files looks like:

generationTime = YYYY_MM_DDThh:mm:ss:dddddddZ;

The revised calibration factors were installed at 2003-06-06T00:00:00.000000Z. The product generation time should be compared to this installation time to determine if the product metadata file (.IMD) has original or revised factors. The bit depth is either 16 bits or 8 bits and in the .IMD files looks like:

```
BitsPerPixel = 16;
```

Conversion to band-integrated radiance is based on the instructions in the following sections corresponding to the product generation time and bit depth. Additionally, the panchromatic band has five possible exposure levels using time-delayed integration (TDI). These values could be 10, 13, 18, 24, or 32 and each has its own calibration factor. The TDI level used during image acquisition for a given product can be found in the .IMD files and looks like:

```
BEGIN_GROUP = IMAGE_1
        TDILevel = 10;
END_GROUP = IMAGE_1
```

If the product was generated after June 6, 2003 at 0:00 GMT, the absolute calibration factors in the .IMD files are the revised factors and should be used for radiance conversion. These factors look like:

```
BEGIN_GROUP = BAND_B
        absCalFactor = 1.604120e-02;
END_GROUP = BAND_B
```

where this is an example for the blue band (QuickBird multispectral Band 1). BAND_P, BAND_B, BAND_G, BAND_R, and BAND_N correspond to the pan, blue, green, red, and nir bands respectively. NOTE: the absolute calibration factors are in scientific notation.

1.1.1 16-Bit Products

11-bit QuickBird data is stored as 16-bit integers. Placeholders are added to account for the five extra bits, but no stretching is performed.

1.1.1.1 Products Generated Before 2003-06-06T00:00:00.000000Z

In this case, the revised K factors listed in Table 1 should be used instead of the original absCalFactors contained in the .IMD files.

Table 1: Revised K Factors for 16-Bit Products

Spectral Band	TDI Level	K(revised) [W-m^{-2}-sr^{-1}-count^{-1}]
Pan	10	8.381880e-02
Pan	13	6.447600e-02
Pan	18	4.656600e-02
Pan	24	3.494440e-02
Pan	32	2.618840e-02
Blue	NA	1.604120e-02
Green	NA	1.438470e-02
Red	NA	1.267350e-02
NIR	NA	1.542420e-02

Conversion from radiometrically corrected image pixels to band-integrated radiance is performed using the following equation:

$$L_{Pixel,Band} = K(revised)_{Band} \cdot q_{Pixel,Band}$$

where $L_{Pixel,Band}$ are top-of-atmosphere band-integrated radiance image pixels [W-m^{-2}-sr^{-1}], $K(revised)_{Band}$ is the revised absolute radiometric calibration factor [W-m^{-2}-sr^{-1}-count^{-1}] for a given band and is listed in Table 1, and $q_{Pixel,Band}$ are radiometrically corrected image pixels [counts].

1.1.1.2 Products Generated After 2003-06-06T00:00:00.000000Z

For products generated after June 6, 2003 at 0:00 GMT, the revised K factors are correctly listed in the absCalFactor line in the .IMD files. Therefore they should match the values in Table 1. Conversion to band-integrated radiance uses these absCalFactors and follows:

$$L_{Pixel,Band} = absCalFactor_{Band} \cdot q_{Pixel,Band}$$

where $L_{Pixel,Band}$ are top-of-atmosphere band-integrated radiance image pixels [W-m^{-2}-sr^{-1}], $absCalFactor_{Band}$ is the absolute radiometric calibration factor [W-m^{-2}-sr^{-1}-count^{-1}] for a given band and is listed in the .IMD files, and $q_{Pixel,Band}$ are radiometrically corrected image pixels [counts].

1.1.2 8-Bit Products

For 8-bit products, 11-bit QuickBird data must be rescaled to 8 bits (unless the original 11-bit image data has a dynamic range less than 8 bits in which case no scaling is performed). This is done on a product-by-product basis to maximize the dynamic range of the data stored in the 8-bit format. Subsequently, each 8-bit product has its own corresponding absolute calibration factors.

1.1.2.1 Products Generated Before 2003-06-06T00:00:00.000000Z

Products generated before June 6, 2003 at 0:00 GMT have original absolute calibration factors that must be modified to revised calibration factors by multiplying by a k′ conversion factor listed in Table 2:

Table 2: k′ Conversion Factors for 8-Bit Products

Spectral Band	TDI Level	k′
Pan	10	1.02681367
Pan	13	1.02848939
Pan	18	1.02794702
Pan	24	1.02989685
Pan	32	1.02739898
Blue	NA	1.12097834
Green	NA	1.37652632
Red	NA	1.30924587
NIR	NA	0.98368622

Conversion to band-integrated radiance uses the absCalFactors and the k′ conversion factors according to the following equation:

$$L_{Pixel,Band} = absCalFactor_{Band} \cdot k'_{Band} \cdot q_{Pixel,Band}$$

where $L_{Pixel,Band}$ are top-of-atmosphere band-integrated radiance image pixels [W-m^{-2}-sr^{-1}], $absCalFactor_{Band}$ is the original absolute radiometric calibration factor [W-m^{-2}-sr^{-1}-count^{-1}] for a given band and is listed in the .IMD files, k'_{Band} is a conversion factor to go from original absolute calibration factors to revised factors for a given band and is listed in Table 2, and $q_{Pixel,Band}$ are radiometrically corrected image pixels [counts].

1.1.2.2 Products Generated After 2003-06-06T00:00:00.000000Z

For products generated after June 6, 2003 at 0:00 GMT, the revised k factors are correctly listed in the absCalFactor line in the .IMD files. Conversion to band-integrated radiance uses these absCalFactors and follows:

$$L_{Pixel,Band} = absCalFactor_{Band} \cdot q_{Pixel,Band}$$

where $L_{Pixel,Band}$ are top-of-atmosphere band-integrated radiance image pixels [W-m^{-2}-sr^{-1}], $absCalFactor_{Band}$ is the absolute radiometric calibration factor [W-m^{-2}-sr^{-1}-count^{-1}] for a given band and is listed in the .IMD files, and $q_{Pixel,Band}$ are radiometrically corrected image pixels [counts].

1.2 Band-Averaged Spectral Radiance [W-m^{-2}-sr^{-1}-μm^{-1}]

The second step in conversion to top-of-atmosphere spectral radiance is to divide the band-integrated radiance by an effective bandwidth ($\Delta\lambda$). Effective bandwidths were calculated from the QuickBird relative spectral radiance response curves for each band and are listed in Table 3:

Table 3: QuickBird Effective Bandwidths ($\Delta\lambda$)

Spectral Band	Effective Bandwidth [μm]
Pan	0.398
Blue	0.068
Green	0.099
Red	0.071
NIR	0.114

Conversion from band-integrated radiance to band-averaged spectral radiance is performed using the following equation:

$$L_{\lambda_{Pixel,Band}} = \frac{L_{Pixel,Band}}{\Delta\lambda_{Band}}$$

where $L\lambda_{Pixel,Band}$ are top-of-atmosphere band-averaged spectral radiance image pixels [W-m^{-2}-sr^{-1}-μm^{-1}], $L_{Pixel,Band}$ are top-of-atmosphere band-integrated radiance image pixels [W-m^{-2}-sr^{-1}], and $\Delta\lambda_{Band}$ is the effective bandwidth [μm] for a given band.