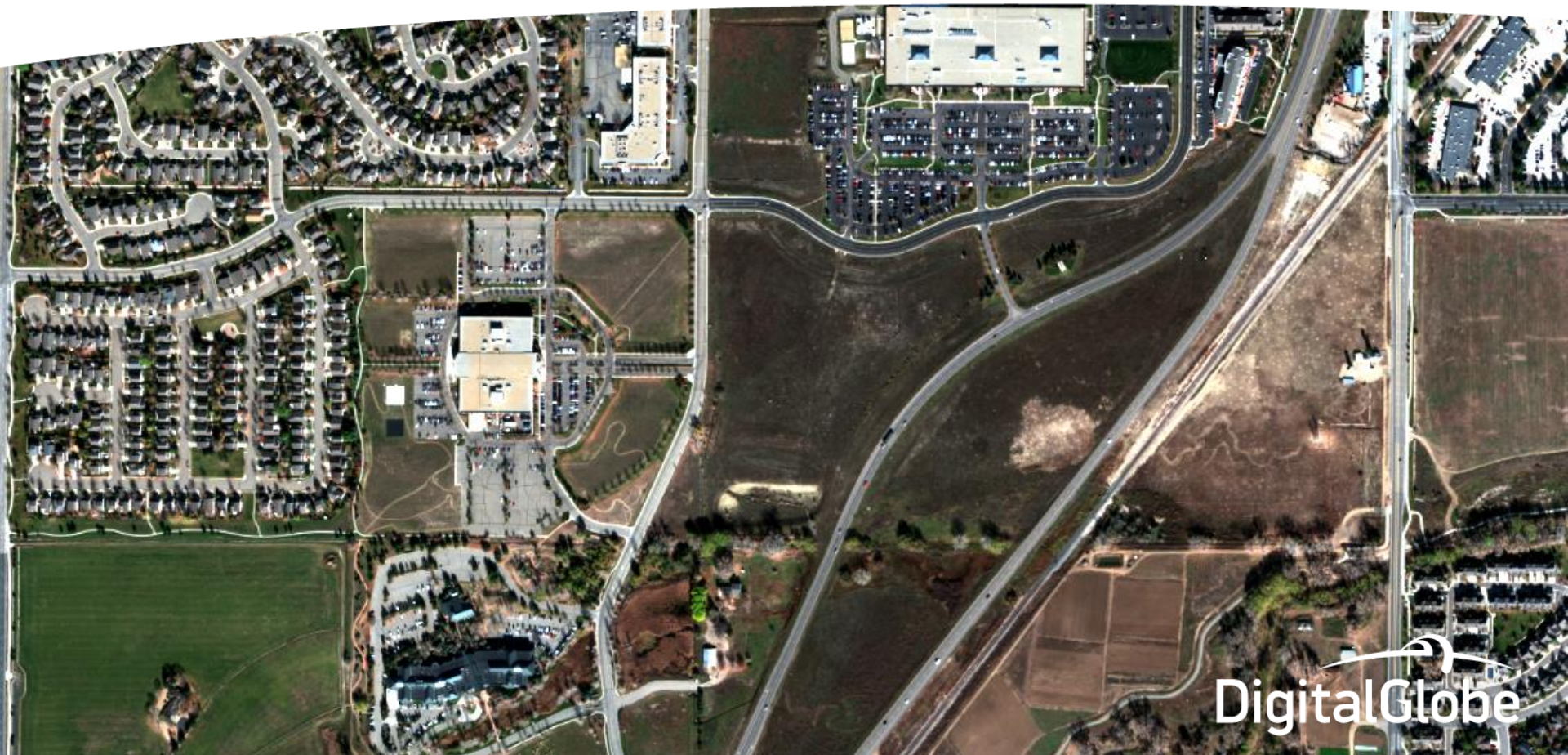


Absolute Radiometric Calibration: 2016v0

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Update: 6/6/2017 GE01 and CAVIS

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Absolute Radiometric Correction of DigitalGlobe Products

DigitalGlobe sensor products are delivered to the customer as relative radiometrically corrected image pixels. Their values are a function of how much spectral radiance enters the telescope aperture and the instrument conversion of that radiation into a digital signal. That signal depends on the spectral transmission of the telescope and filters, the throughput of the telescope, the spectral quantum efficiency of the detectors, and the analog to digital conversion. Therefore, image pixel data are unique to each sensor and should not be directly compared to imagery from other sensors in a radiometric/spectral sense. In addition, bands taken at different TDI levels may give misleading spectral information if left in digital number space. Image pixels should be converted to top-of-atmosphere spectral radiance at a minimum.

A pre-flight calibration has been performed and these data are provided in the .IMD metadata file that is delivered with the imagery. Since launch, DigitalGlobe has performed an extensive vicarious calibration campaign to provide an adjustment to the pre-launch values. The top-of-atmosphere radiance, L , in units of $W\mu m^{-1} m^{-2} sr^{-1}$, is then found from the DigitalGlobe image product for each band by converting from digital numbers (DN) using the equation,

$$L = GAIN * DN * \left(\frac{abscalfactor}{effectivebandwith} \right) + OFFSET$$

The TDI specific *abscalfactor* and *effectiveBandwidth* are delivered with the imagery in the metadata file. The digital number, *DN*, is the pixel value found in the imagery. The *Gain* and *Offset* are the absolute radiometric calibration band dependent adjustment factors that are given in Table 1. Note that these are not necessarily stagnant values and they are revisited annually.

Table 1. New Calibration Adjustment Factors

	WORLDVIEW-3		WORLDVIEW-2		GEOEYE-1		QUICKBIRD		WORLDVIEW-1		IKONOS	
Cal Version	2016v0.Int*				2016v3.Int**		2016v0.Int*				2014v3	
BAND	GAIN	OFFSET	GAIN	OFFSET	GAIN	OFFSET	GAIN	OFFSET	GAIN	OFFSET	GAIN	OFFSET
PAN	0.950	-3.629	0.942	-2.704	0.970	-1.926	0.870	-1.491	1.016	-1.824	0.907	-4.461
COASTAL	0.905	-8.604	1.151	-7.478								
BLUE	0.940	-5.809	0.988	-5.736	1.053	-4.537	1.105	-2.820			1.073	-9.699
GREEN	0.938	-4.996	0.936	-3.546	0.994	-4.175	1.071	-3.338			0.990	-7.937
YELLOW	0.962	-3.649	0.949	-3.564								
RED	0.964	-3.021	0.952	-2.512	0.998	-3.754	1.060	-2.954			0.940	-4.767
REEDGE	1.000	-4.521	0.974	-4.120								
NIR1	0.961	-5.522	0.961	-3.300	0.994	-3.870	1.020	-4.722			1.043	-8.869
NIR2	0.978	-2.992	1.002	-2.891								
SWIR1	1.200	-5.546										
SWIR2	1.227	-2.600										
SWIR3	1.199	-2.309										
SWIR4	1.196	-1.676										
SWIR5	1.262	-0.705										
SWIR6	1.314	-0.669										
SWIR7	1.346	-0.512										
SWIR8	1.376	-0.372										

**GE01 update on 6/6/2017

*Includes 2016 vicarious season

Note: Use these adjustments for imagery over all years of sensors lifetime

Table 2. CAVIS Calibration Adjustment Factors Version for reference: 2016v1.L4

WorldView-3 CAVIS		
CAL VERSION	2016v1.L4**	
BAND	GAIN	OFFSET
DESERT CLOUDS	1.377	0
AEROSOL-1	1.051	0
GREEN	0.816	0
AEROSOL-2	0.869	0
WATER-1	0.849	0
WATER-2	0.677	0
WATER-3	0.819	0
NDVI-SWIR	0.842	0
CIRRUS	1.000	0
SNOW	0.897	0
AEROSOL-3	1.081	0
AEROSOL-3 P	1.076	0

**CAVIS updated on 6/6/2017

Libya-4 Model used to derive CAVIS calibration adjustment factors.

Step 2: Conversion to TOA Reflectance

- The following equation is used to convert the at-sensor radiance to top of atmosphere reflectance

$$\rho_{\lambda_{\text{Pixel,Band}}} = \frac{L_{\lambda_{\text{Pixel,Band}}} \cdot d_{\text{ES}}^2 \cdot \pi}{E_{\text{sun}}_{\lambda_{\text{Band}}} \cdot \cos(\theta_S)}$$

- “L” is at-sensor radiance calculated with info from previous slides
- Calculations are performed independently for each band and pixel
- “d_{ES}” is the earth-Sun distance in AU for the date (TLCTime gives the date and time of the collection so you may calculate “d”)
- E_{sun} is the band-averaged Solar exoatmospheric irradiance @1 AU (see Slide 7&8). DG calibration team uses the Thuillier 2003 solar curve for their calculations
- Theta is the solar zenith angle (90-meanSunEl from IMD file)

Further information is available in Radiometric Use of WorldView-3 Imagery Technical Note

Table 4. Solar exoatmospheric irradiance for reference (@1 AU)

Worldview-2			
BAND	Thuillier 2003	ChKur	WRC
PAN	1571.36	1575.38	1580.76
COASTAL	1773.81	1759.24	1757.77
BLUE	2007.27	1977.4	1974.29
GREEN	1829.62	1857.89	1856.03
YELLOW	1701.85	1738.11	1738.59
RED	1538.85	1554.95	1559.35
REDEGE	1346.09	1302.19	1342.05
NIR1	1053.21	1061.4	1069.59
NIR2	856.599	856.816	861.201

Worldview-1			
BAND	Thuillier 2003	ChKur	WRC
PAN	1478.62	1481.48	1487.92

QuickBird			
BAND	Thuillier 2003	ChKur	WRC
PAN	1370.92	1376.3	1381.72
BLUE	1949.59	1926.55	1924.62
GREEN	1823.64	1844.26	1842.81
RED	1553.78	1571.58	1574.65
NIR	1102.85	1107.47	1113.72

GeoEye-1			
BAND	Thuillier 2003	ChKur	WRC
PAN	1610.73	1614.88	1619.49
BLUE	1993.18	1966.03	1963.53
GREEN	1828.83	1857.12	1855.25
RED	1491.49	1500.38	1506.29
NIR	1022.58	1029.61	1037.7

IKONOS			
BAND	Thuillier 2003	ChKur	WRC
PAN	1353.25	1358.59	1364.06
BLUE	1921.26	1902.54	1901.19
GREEN	1803.28	1827.32	1826.04
RED	1517.76	1526.48	1532.48
NIR	1145.8	1150.51	1155.37

Worldview-3 (Main & SWIR)			
BAND	Thuillier 2003	ChKur	WRC
PAN	1574.41	1578.28	1583.58
COASTAL	1757.89	1743.9	1743.81
BLUE	2004.61	1974.53	1971.48
GREEN	1830.18	1858.1	1856.26
YELLOW	1712.07	1748.87	1749.4
RED	1535.33	1550.58	1555.11
REDEGE	1348.08	1303.4	1343.95
NIR1	1055.94	1063.92	1071.98
NIR2	858.77	858.632	863.296
SWIR 1	479.019	478.873	494.595
SWIR 2	263.797	257.55	261.494
SWIR 3	225.283	221.448	230.518
SWIR 4	197.552	191.583	196.766
SWIR 5	90.4178	86.5651	80.365
SWIR 6	85.0642	82.0035	74.7211
SWIR 7	76.9507	74.7411	69.043
SWIR 8	68.0988	66.3906	59.8224

Table 6. Solar exoatmospheric irradiance for reference (@1 AU)

WorldView-3 CAVIS			
BAND	Thuillier 2003	ChKur	WRC
Desert Clouds	1718.25	1712.25	1712.92
Aerosol-1	2001.13	1968.46	1966.77
Green	1831.3	1861.44	1858.48
Aerosol-2	1537.38	1554.15	1558.97
Water-1	955.658	955.79	974.37
Water-2	866.791	869.104	864.878
Water-3	807.875	808.077	787.589
NDVI-SWIR	460.196	460.905	478.788
Cirrus	361.412	355.142	363.49
Snow	230.349	226.394	234.085
Aerosol-3	89.1345	85.8585	79.5456
Aerosol-3 Parallax	89.1345	85.8585	79.5456



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