Innovative Imaging & Research

Enhanced Absolute and Radiometric Calibration for Digital Aerial Cameras

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Background

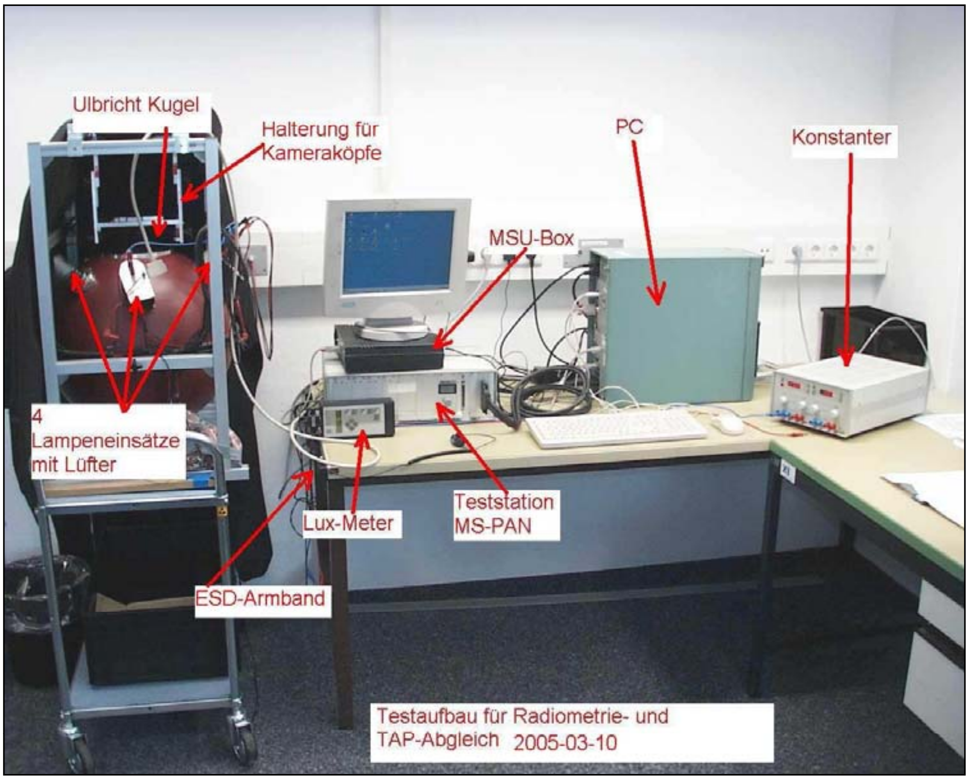
- Z/I is upgrading their radiometric calibration process for DMC and RMK-D digital cameras to include absolute radiometry
  - Enabling the development of a new suite of **remote sensing** products that historically have been dominated by satellite based systems
  - Builds upon relative radiometric calibration processes (Flat Fielding or Normalization, linearity, band-to-band)

Relative Radiometry

- Pixel-to-pixel to correct
  - Vignetting (fall off in signal off axis) image normalization or flat fielding correction
  - Detector variation
- Typical remote sensing industry goal <1% (Landsat Data Continuity Mission (LDCM) Data Specification, March 2000)

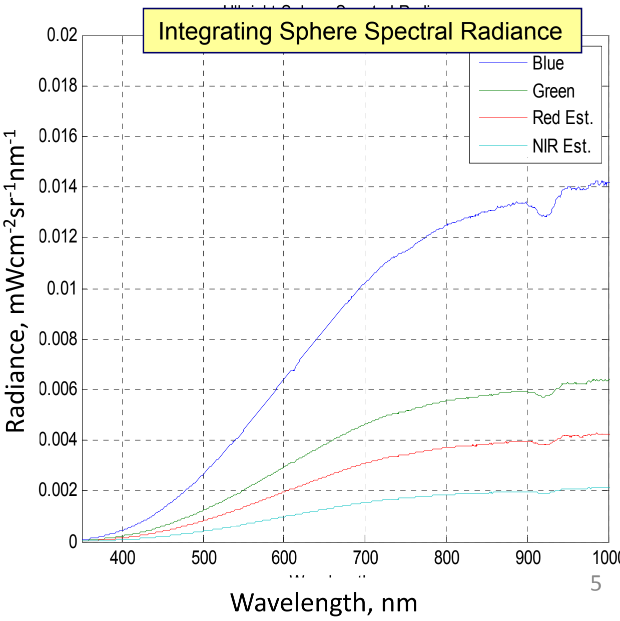
Current Relative Radiometric Test Configuration

Camera and sphere are vertically aligned during laboratory calibration



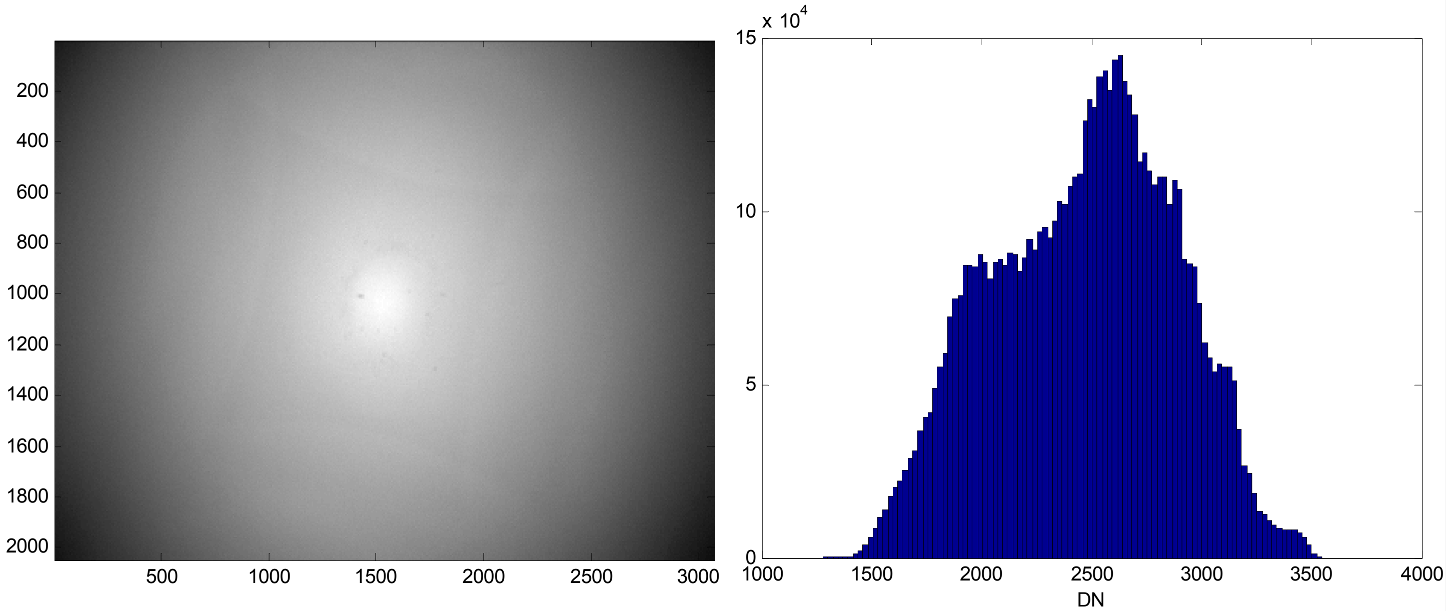
Current Integrating Sphere Lamp Configurations

- Four Tungsten lamp configurations
  - Blue (2 x 50W and 2 x 20W)
  - Green (2 x 20W and 2 x 10W)
  - Red (4 x 10W)
  - NIR (4 x 5W)
  - Pan (4 x 5W)
- Lamps interchanged to adjust radiance level
- Approximate factor of 7 difference between blue and NIR lamp radiance level



Sample Integrating Sphere Raw Image and Corresponding Histogram

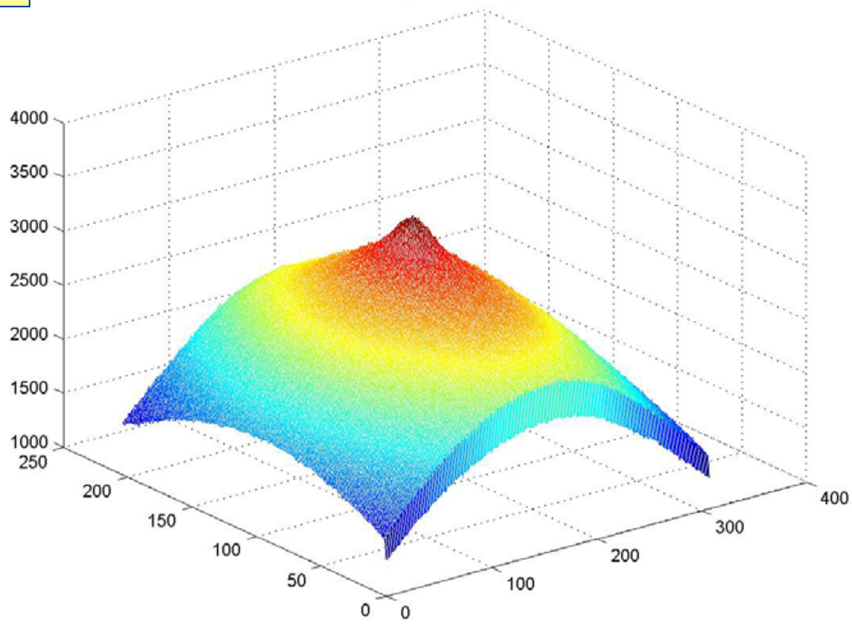
NIR Channel



Signal changes by more than a factor of 2

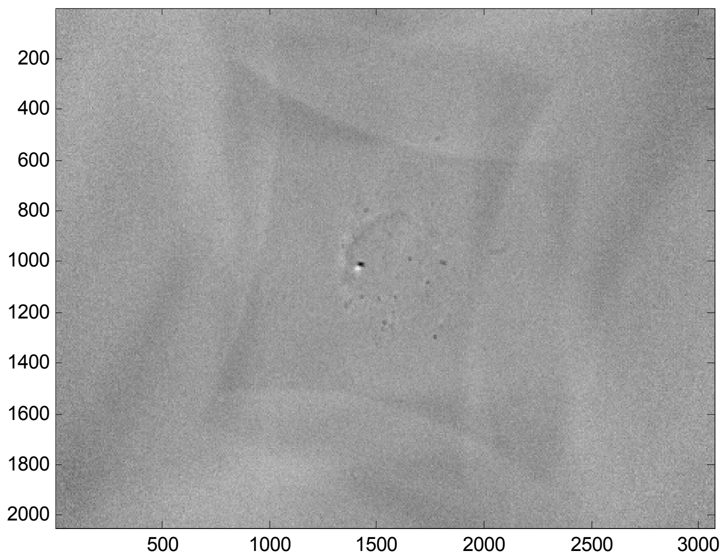
Sample DMC Integrating Sphere Raw Image

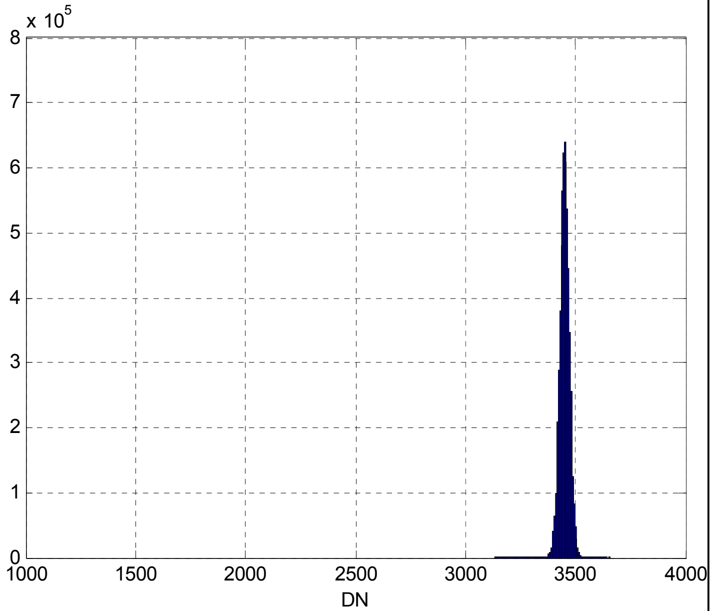
NIR Channel



Integrating Sphere Normalized Image and Corresponding Histogram

NIR channel





Why Have An Absolute Radiometry Aerial Imaging System?

- Predicts the performance of the multispectral imager a priori
- Simulates satellite remote sensing systems
- Supports the ability to atmospherically correct products to surface reflectance

Absolute Radiometry

- Conversion of DN to engineering units of radiance (remote sensing)
- Typical remote sensing goal is <5% difference from a National Standard (Landsat Data Continuity Mission (LDCM) Data Specification, March 2000)

In general if a system has good absolute radiometry it has good color quality

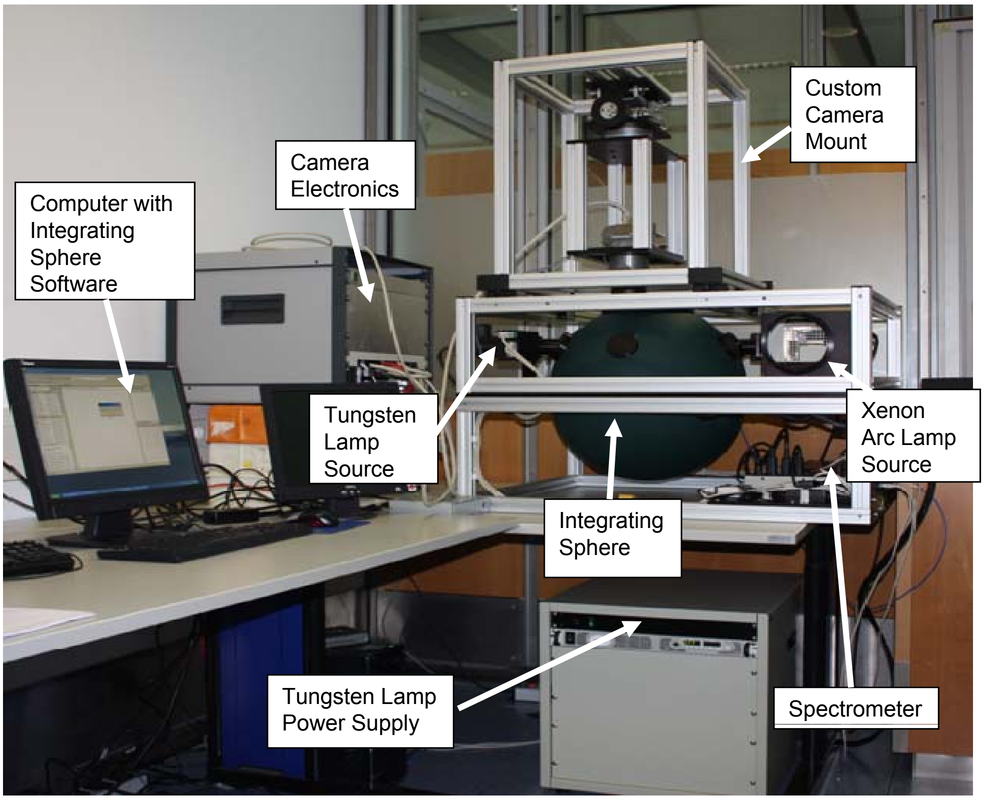
Absolute Radiometry

$$L_{sensor} = C \bullet (DN - DN_{Dark})$$

Where:

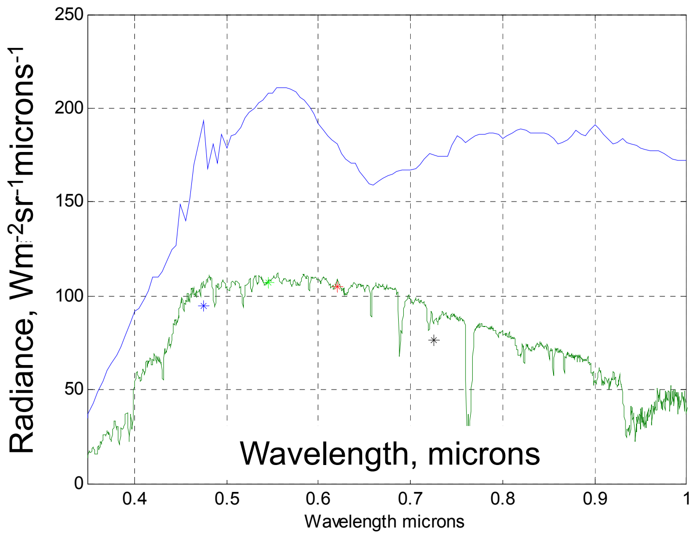
- L_{sensor} = At sensor radiance [W/(m^{2}srμm)] at each pixel
- C = Calibration coefficient [counts/(W/(m^{2}srμm)]
- DN = Digital number [counts] at each pixel
- DN_{Dark} = Dark frame digital number [counts] at each pixel

Absolute Radiometric Calibration System



Integrating Sphere Spectral Radiance

- Designed to approximately emulate At-Sensor radiance for a 50% gray target with solar zenith angle of 60 degrees



Absolute Radiometric Calibration

$$C = \frac{1}{DN}\frac{\int_0^\infty L(\lambda)S(\lambda)d\lambda}{\int_0^\infty S(\lambda)d\lambda}$$

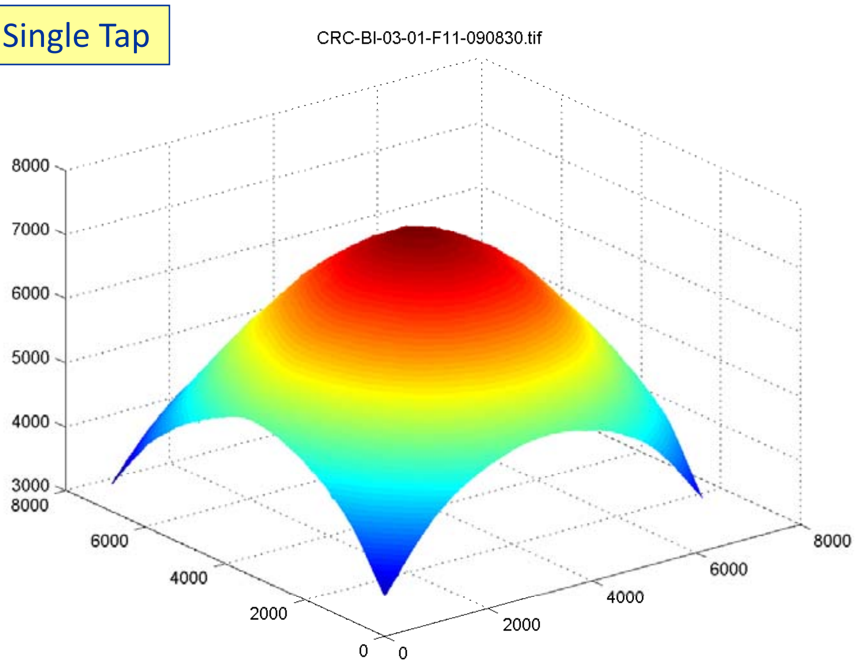
Where:

DN	Digital Number for a pixel
L	Spectral radiance of Integrating sphere [W/(m^2 sr μm)]
S	System spectral response
C	Calibration coefficient [(W/(m^2 sr μm))/DN]

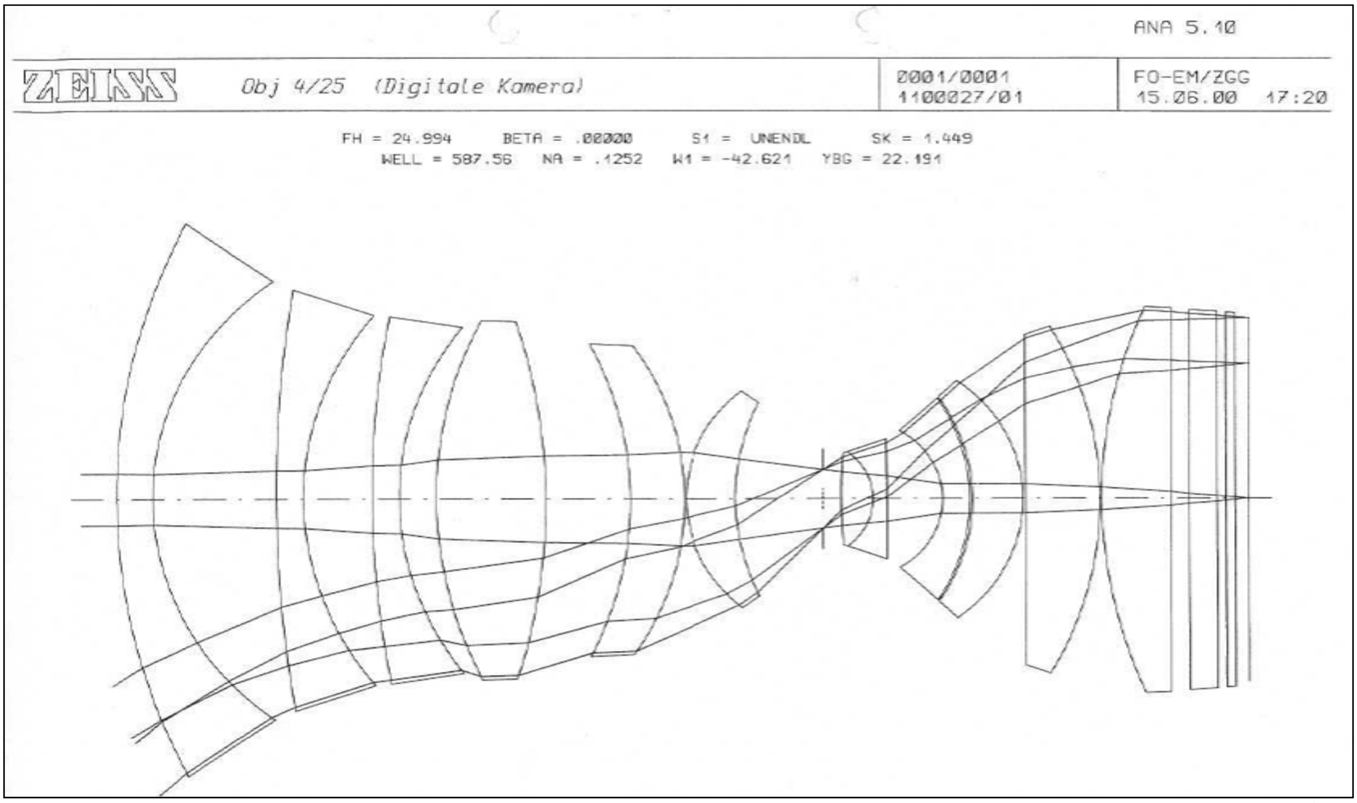
Using the spectral response and Integrating sphere radiance both normalization and absolute calibration will be accomplished simultaneously

RMK-D Vignetting Image New Integating Sphere

Blue Channel – Single Tap

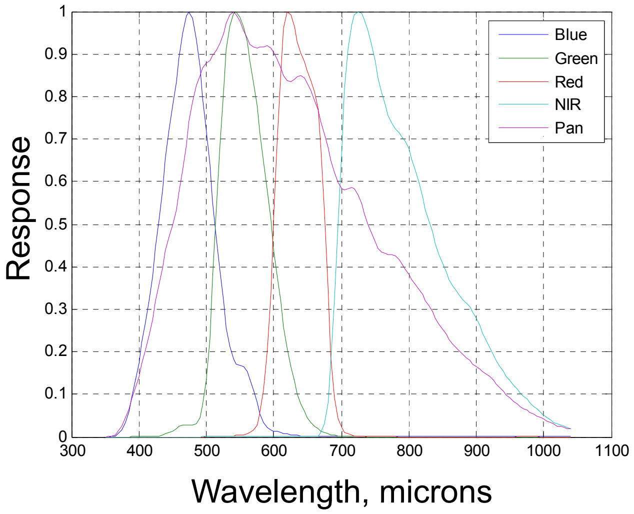


DMC MS Camera Optical Schematic



DMC Spectral Response

Normalized Response

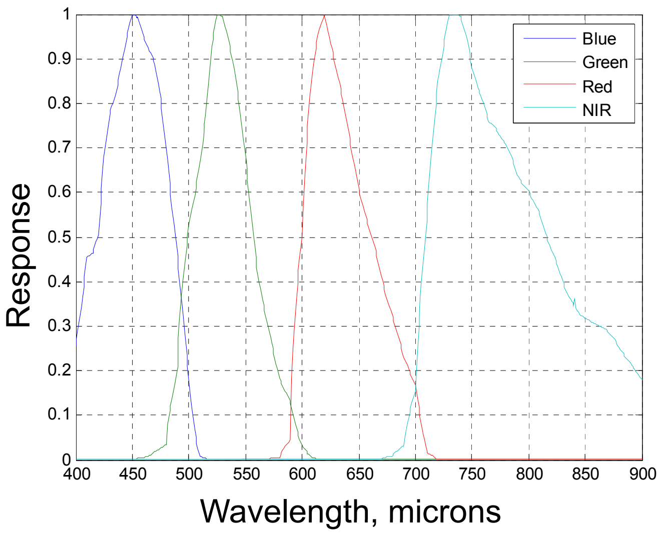


Description

Band	Peak (nm)	50% Points (nm)	10% Points (nm)
Blue	475	429-514	319-579
Green	545	514-600	497-635
Red	620	600-676	584-690
NIR	725	695-831	681-968
Pan	540	450-739	392-944

RMK-D Spectral Response

Normalized Response



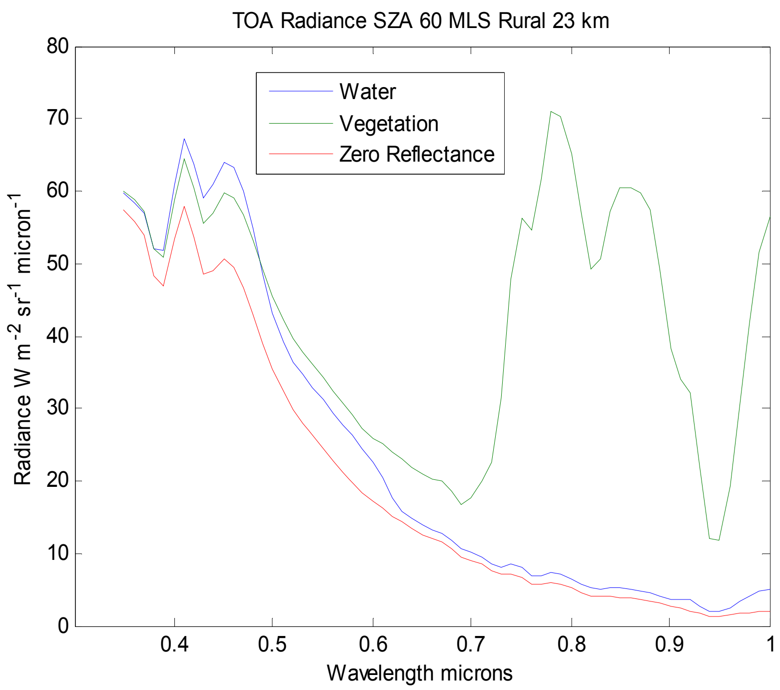
Description

Band	Peak (nm)	50% Points (nm)	10% Points (nm)
Blue	450	419-488	390-503
Green	525	499-557	482-592
Red	620	600-662	530-704
NIR	733	709-816	695-921

Benefits of Atmospherically Corrected Image Products

- Reflectance maps enable:
  - Change detection with reduced influence of atmosphere and solar illumination variations
  - Spectral library-based classifiers
  - Improved comparisons between different instruments and acquisitions
  - Derived products such as Normalized Difference Vegetation Index (NDVI)

Importance of Atmospheric Correction

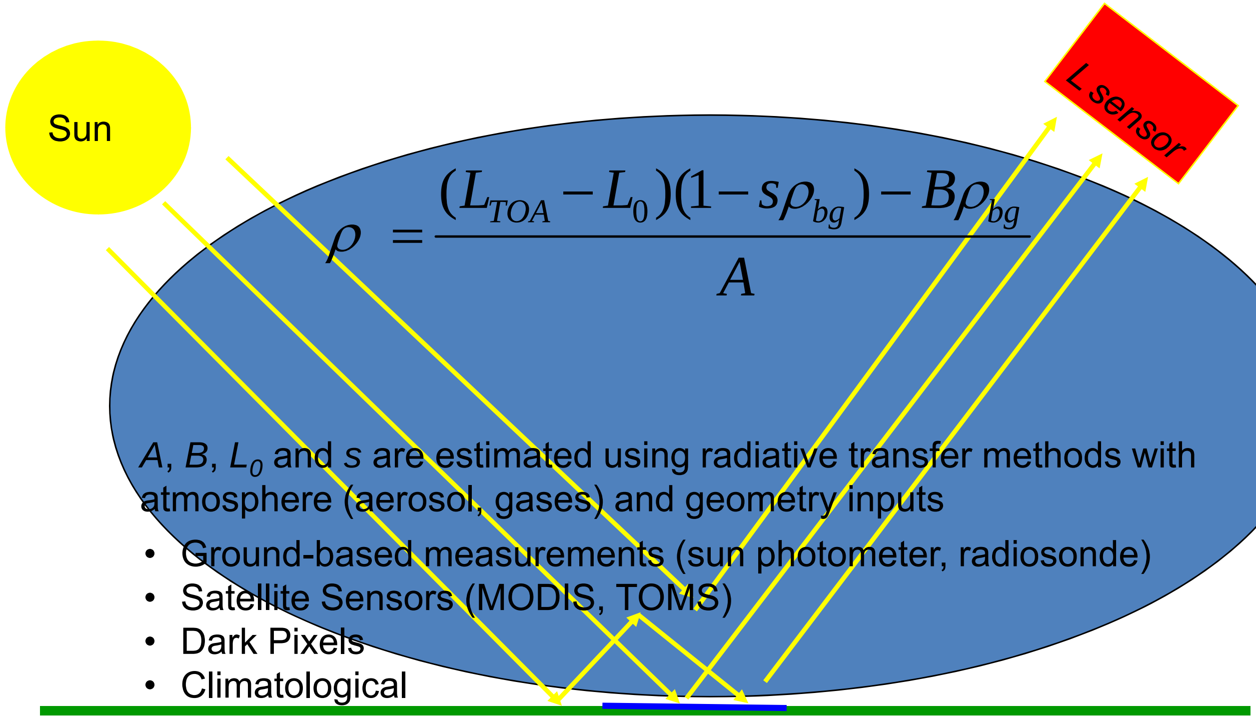


Surface Reflectance Radiative Transfer Methods

$$\rho = \frac{(L_{TOA} - L_0)(1 - s\rho_{bg}) - B\rho_{bg}}{A}$$

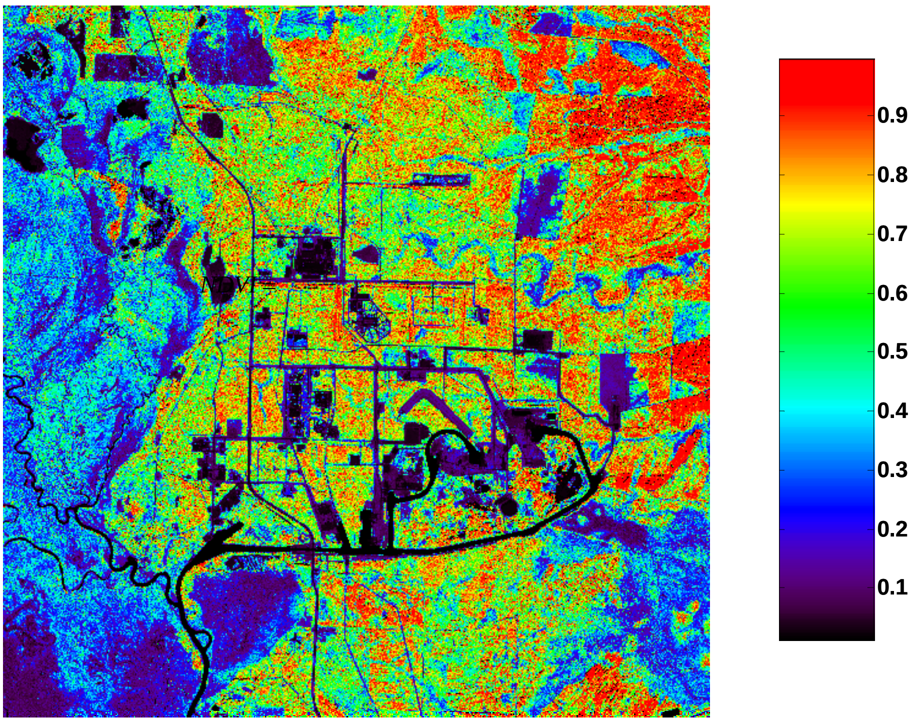
A, *B*, L_0 and *s* are estimated using radiative transfer methods with atmosphere (aerosol, gases) and geometry inputs

- Ground-based measurements (sun photometer, radiosonde)
- Satellite Sensors (MODIS, TOMS)
- Dark Pixels
- Climatological



Atmospherically Corrected NDVI from IKONOS Imagery (Example)

$$NDVI = \frac{(\rho_{NIR} - \rho_{Red})}{(\rho_{NIR} + \rho_{Red})}$$



NASA Stennis Space Center January 15, 2002

I 2 R

Expected Performance

- Initial analysis indicates laboratory radiometric calibration for DMC and RMK-D should be better than 3% and comparable to satellite-based land imagers
- Vicarious calibration processes will be necessary to validate radiometric performance in flight

I 2 R

Summary

- Z/I has instituted an absolute radiometric calibration process that will enable
  - Development of a new generation of remote sensing products for framing cameras
  - Improved operation for the DMC and RMK-D

Acknowledgements

- Z/I staff in Aalen, Germany and Huntsville Alabama, USA
- I2R staff in Mississippi, USA

DMC / IKONOS COMPARISON

	DMC			IKONOS		
Band	Peak (nm)	50% Points (nm)	10% Points (nm)	Peak (nm)	50% Points (nm)	10% Points (nm)
Blue	475	429-514	319-579	495	445-516	426-534
Green	545	514-600	497-635	550	506-595	489-611
Red	620	600-676	584-690	680	632-698	611-721
NIR	725	695-831	681-968	780	757-853	724-882
Pan	540	450-739	392-944	620	526-937	475-1031