I2R Innovative Imaging & Research

Radiometric Correction Workflow for Aerial Imaging Applications

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Aerial Imaging Market Forces

- Drive to increase acquisition efficiency to reduce overall operation costs
  - Fly at higher altitudes to increase coverage
- Drive to increase operational flight envelope to maximize flight opportunities
  - Fly at non-optimum illumination and atmospheric conditions

Camera Focal Plane Technology Advancements

- Camera focal planes are evolving to meet this demand
  - Array size is increasing
  - Pixel size is decreasing

	DMC I	DMC IIe 140	DMC IIe 230	DMC IIe 250
PAN No. of Pixels	13,824 x 7,680	12,096 x 11,200	15,552 x 14,400	16,768 x 14,656
PAN Pixel Size	12 µm	7.2 µm	5.6 µm	5.6 µm
PAN Focal length	120 mm	92 mm	92 mm	112 mm
Pan Cross-track FOV	69.3 deg	50.7 deg	50.7 deg	45.5 deg

As Pixel Size Decreases…

- As pixel size (pitch) decreases
  - The well capacity decreases and the number of photons striking a detector decreases
  - This in turn drives down the total attainable signal for each pixel and decreases the SNR
- The need to understand a sensor's noise properties increases
  - Radiometric calibration becomes essential
    - Enables advanced denoising algorithms

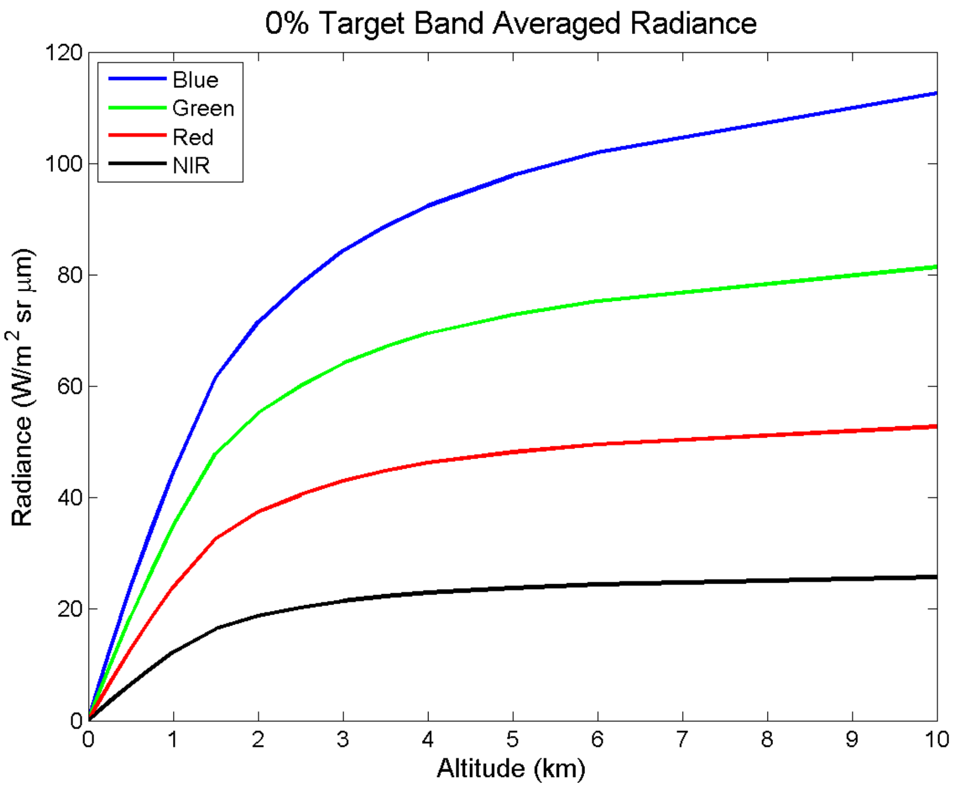
Higher Flight Altitudes Means…

- There's a lot more atmosphere between the sensor and the ground
  - Gaseous molecules – N_2, O_2, Ar, Ne, He, Kr, CO_2, H_2O, CH_4, NO, N_2O, NO_2…
  - Aerosols – fine solid particles such as dust, air pollutants and smoke




Atmosphere

- The atmosphere is anisotropic – not uniform
  - Varies 3-D
- Most of the atmosphere is below 8-10 km
- Pilots require oxygen above ~4km



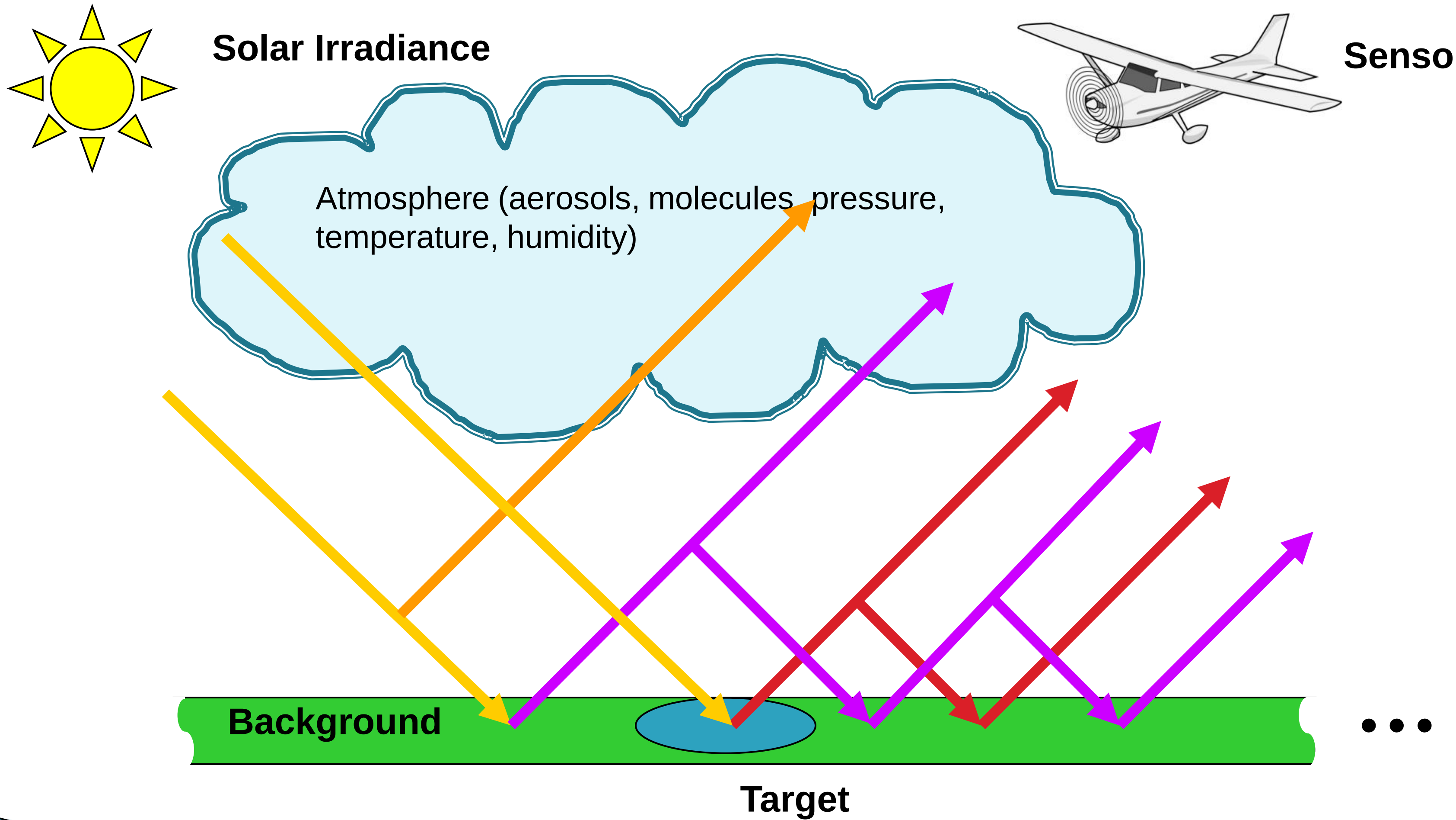
0% reflectance target means the entire signal comes from the atmosphere

Atmosphere

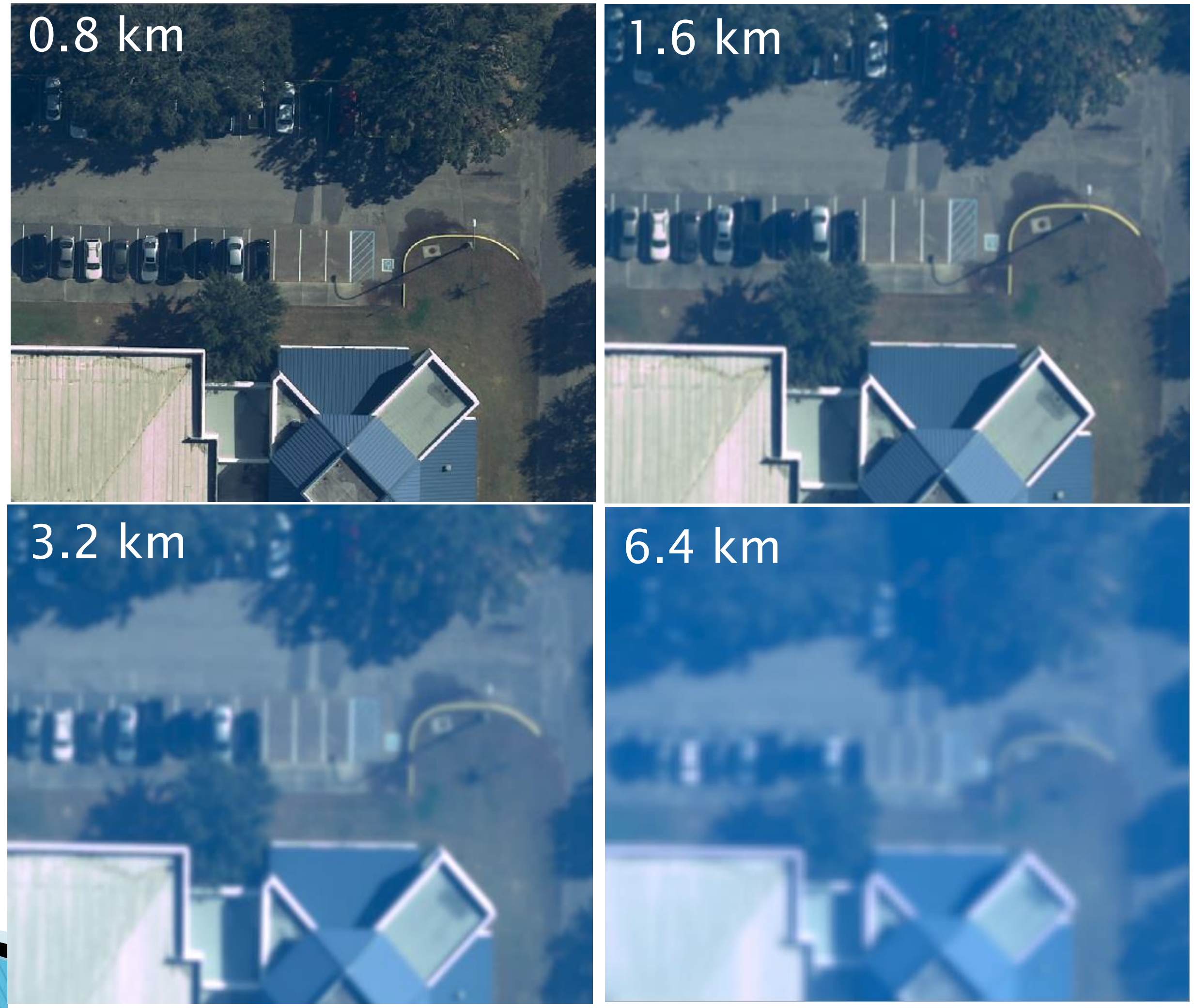
"In most cases, the atmosphere is perceived as a hostile entity whose adverse impacts must be neutralized or eliminated before remotely sensed data can be properly analyzed."

(Schott, "Remote Sensing: The Image Chain Approach", 1997)

What a Sensor Sees



Simulated Image Products – Image Zoomed to View Identical Features



Baseline imagery courtesy of Midwest Aerial Photography

Stennis Space Center

Modtran based rural atmosphere

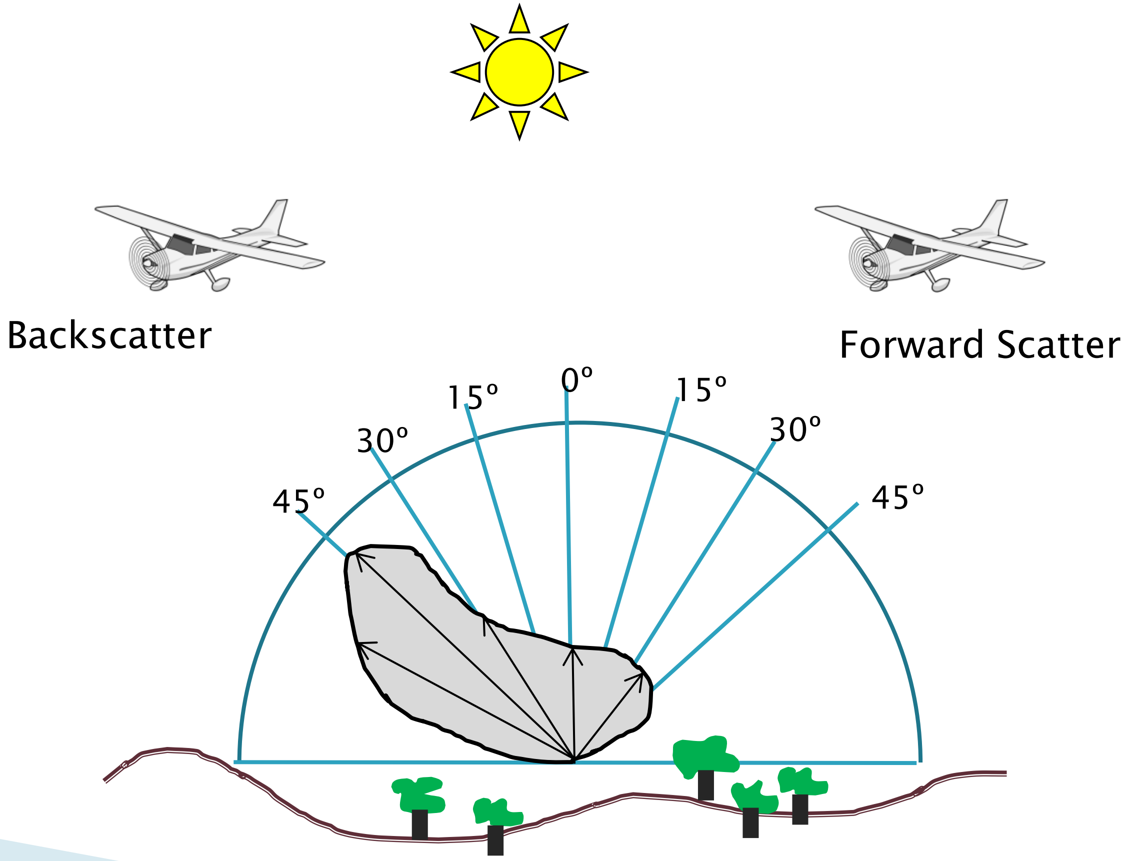
High Visibility

Bidirectional Reflectance

- Both the solar and sensor viewing geometry also effect how a target looks

Blue band – Tampa FL

Imagery courtesy of Quantum Spatial



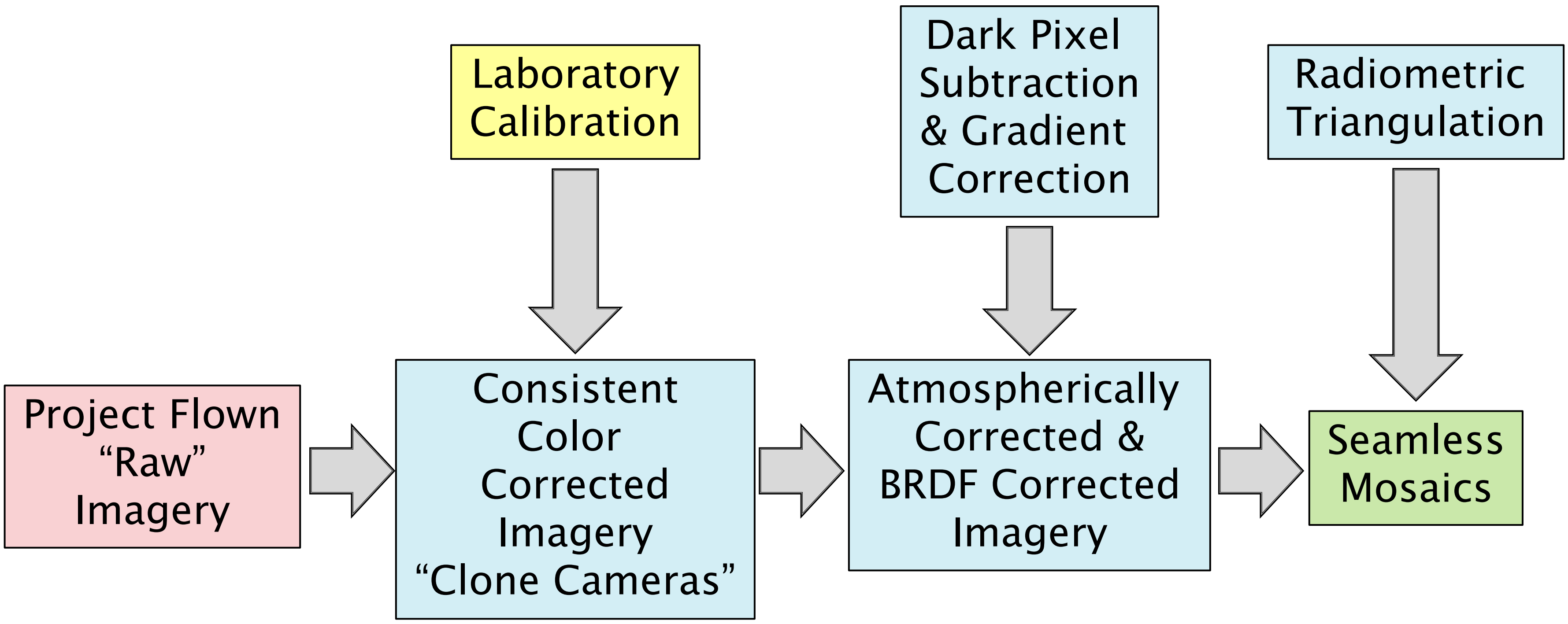
BRDF Example

Aged Asphalt Road

Forward Scatter – Sun in front of camera

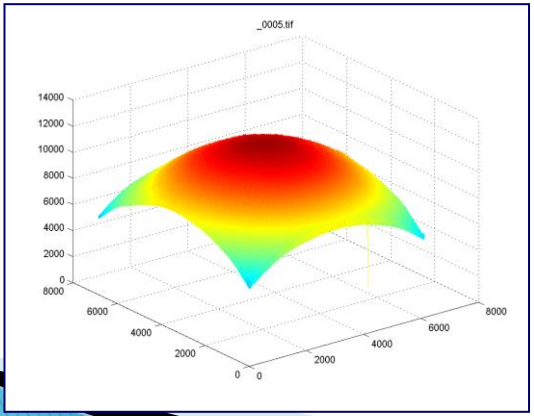
Back Scatter – Sun behind camera

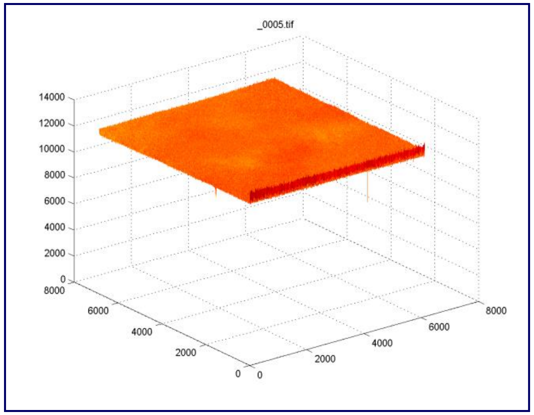
Automated Radiometric Workflow



Laboratory Calibration

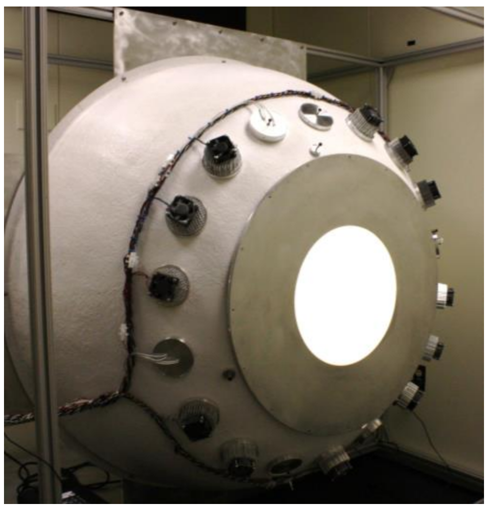
- Relative Radiometric Calibration
  - Dark frame characterization
  - Flat fielding
  - Defective pixel identification and replacement
  - Signal-to-noise ratio evaluation
  - Linearity assessment
  - Shutter variability assessment

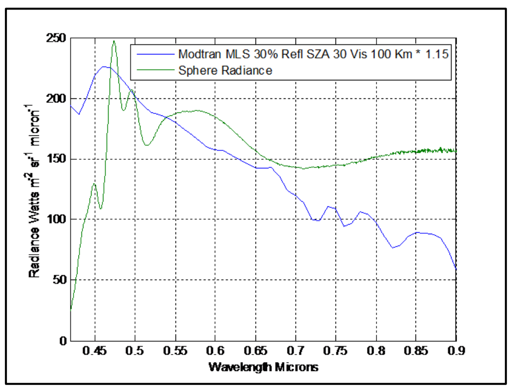


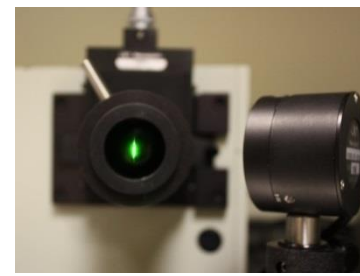


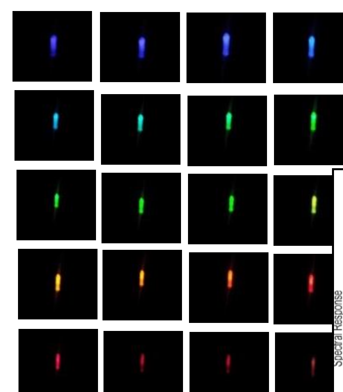
Laboratory Calibration

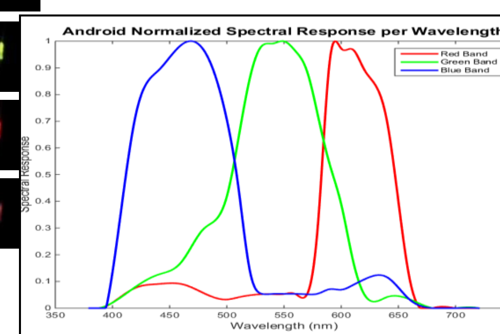
- Absolute Radiometric Calibration
  - Convert image DN’s into physical units
  - Requires spectral response measurement











Significant Haze Example

Intermediate color corrected images

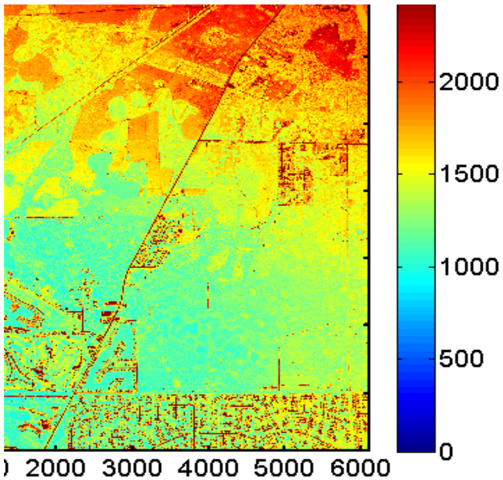
DMCII-250 single flight line (6 images)
Baker County, FLA
~6,000 m
Pan-sharpened Overview Level 2 Mosaic

Haze Reduction – Dark Pixel Subtraction Algorithm

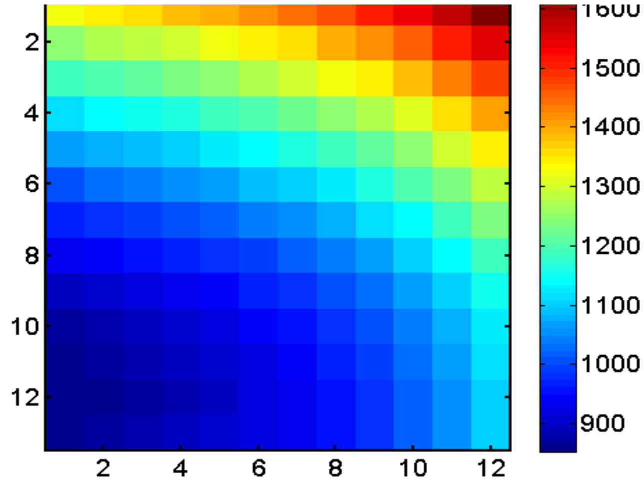
- Dark pixels are located throughout each image within nxn pixel grids
  - 512 x 512 grid for multispectral bands
  - 1024 x 1024 grid for pan band
  - A water mask and other criteria are applied to locate deep dark shadowed land areas
- A reflectance value is assigned to each dark pixel
- The remaining signal is assumed to be haze and is subtracted from each pixel within an image

Example Dark Pixel Subtraction

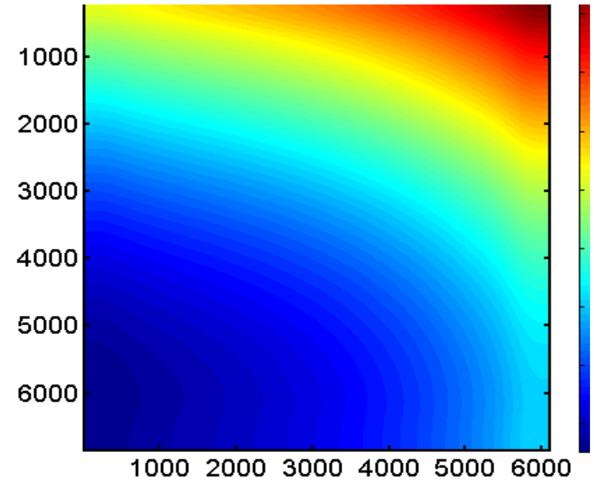
Input Image (Blue Band)



Dark Pixel Grid

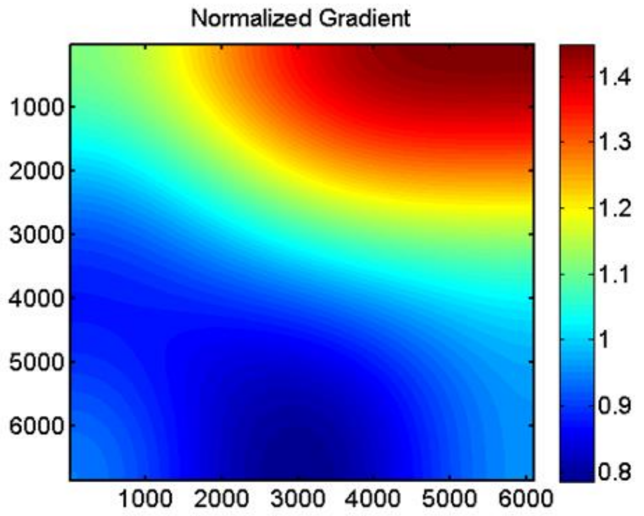


Interpolated Dark Pixel Values



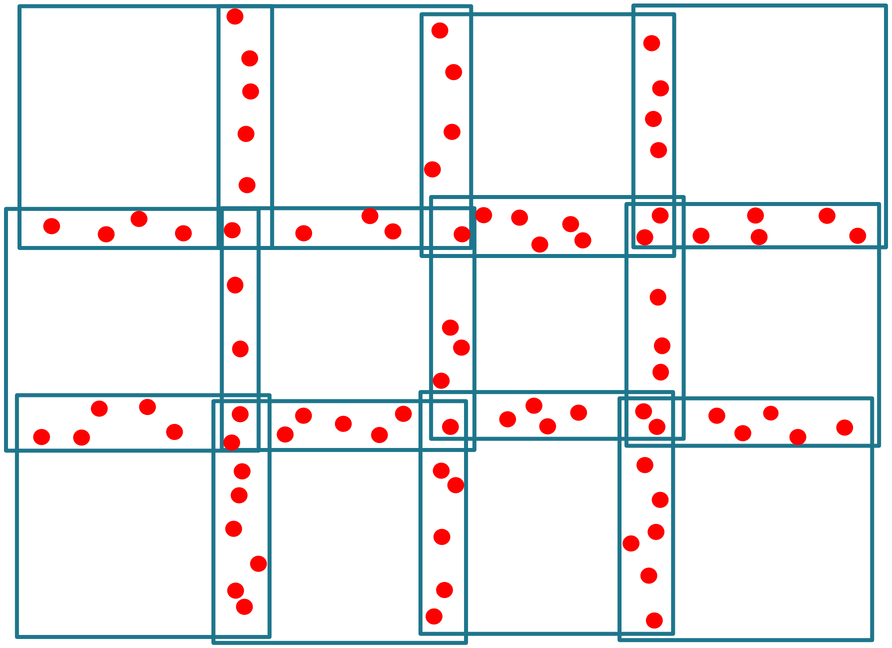
Gradient Effects

- Algorithm removes/reduces any remaining gradient across the image
  - General land cover classification is performed
  - Gradient statistics are collected based on land cover type
    - Multiple images are needed to acquire enough statistics per land cover
    - Algorithm utilizes a physics-based model with statistically based image information
  - Resulting gradient model is applied to each dark pixel subtracted image

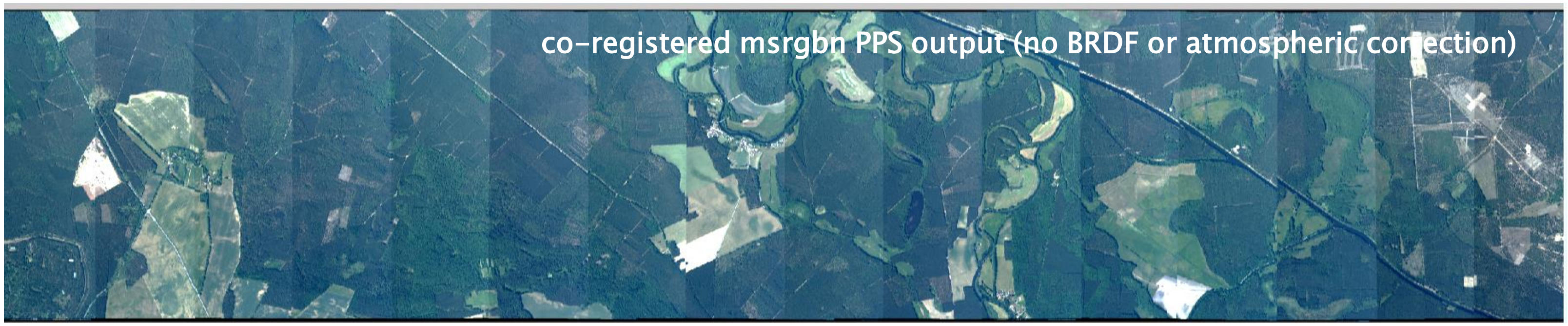


Radiometric Triangulation

- Block-wise Normalization
  - Utilize radiometric information from multiple images within a block to generate a uniform color collection of images
  - Employ tie points
  - Least squares model
- Goal is to *significantly* reduce the workflow associated with generating ortho-mosaics



Sample Mosaic –Brandenburg, Germany DMCII 230 Imagery at 3.2km Altitude



Low Altitude, High Haze example
40 frames/1 line

Sample Mosaic –Brandenburg, Germany DMCII 230 Imagery at 3.2km Altitude

Sample Mosaic –Baker County, Florida DMCII 250 Imagery at 6.0 km Altitude

High Altitude,
High Haze example
84 frames/4 lines

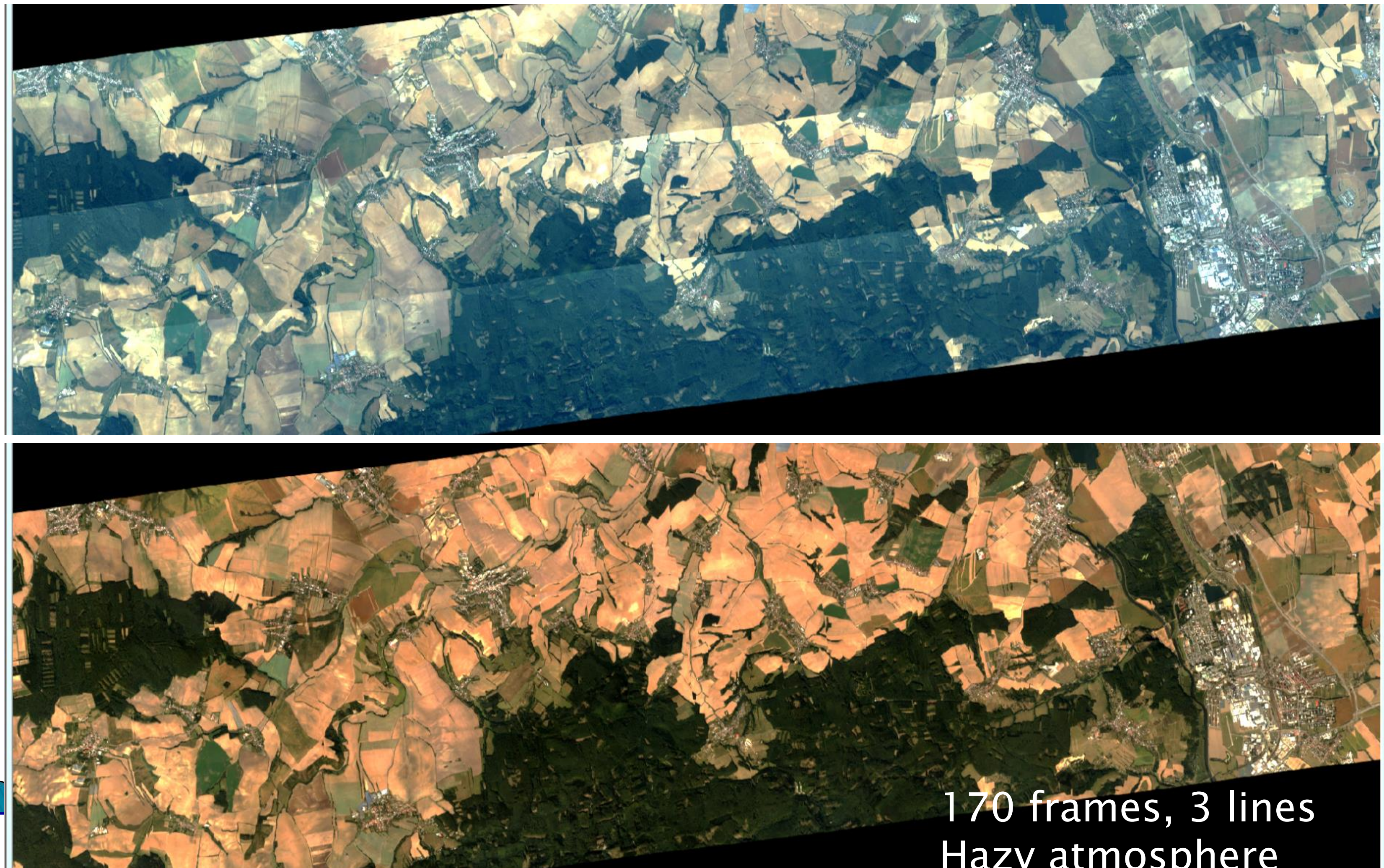
Sample Mosaic –Baker County, Florida DMCII 250 Imagery at 6.0 km Altitude

Sample Mosaic –Tampa, Florida DMCII 250 Imagery at 6.0 km Altitude

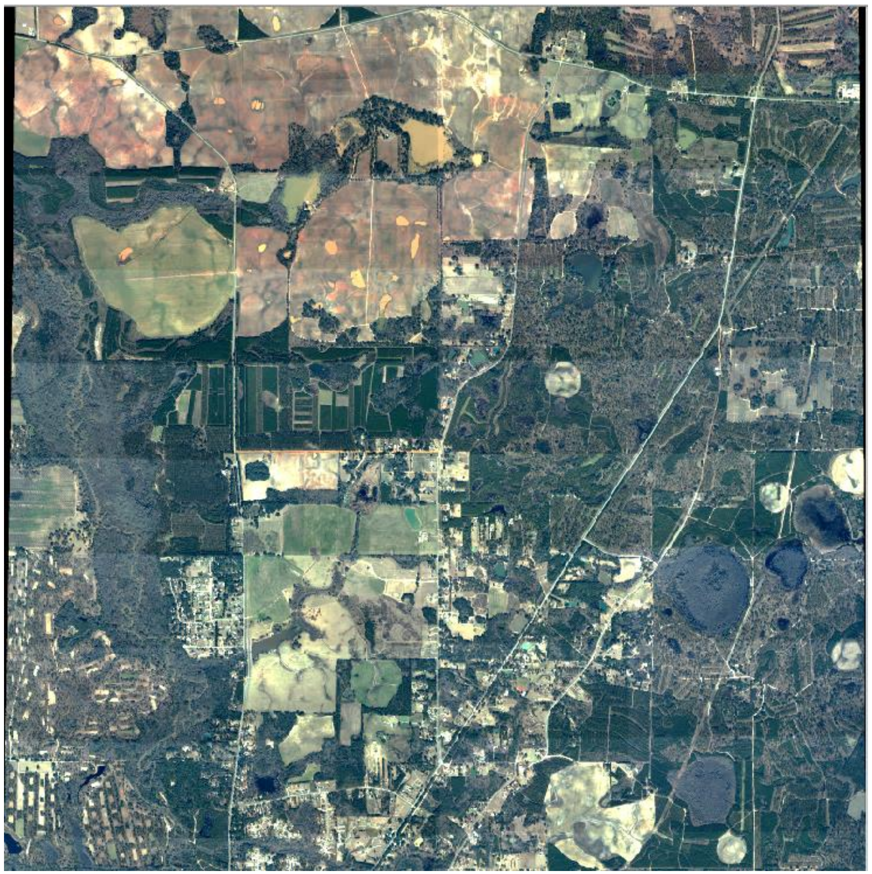
High Altitude, High Haze
Urban/vegetation land cover example

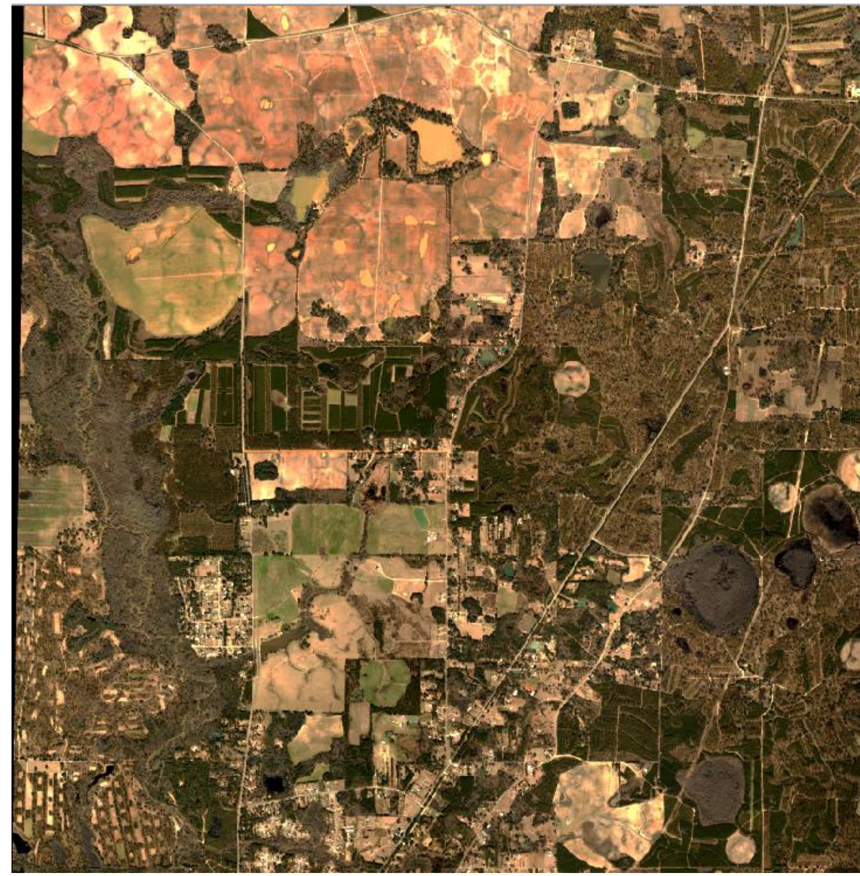
Sample Mosaic –Misawa, Japan DMCII 140 Imagery at 1.5 km Altitude

Sample Mosaic –Germany DMCII 250 Imagery at 4.0 km Altitude



Sample Mosaic –Southwest Georgia DMCII 250 Imagery at 6.0 km Altitude





High Altitude, High Haze
Urban/vegetation land cover example

Summary

- Careful attention to the radiometric workflow enables:
  - Color consistency between cameras
  - Automated atmospheric correction
    - Haze reduction / dark pixel subtraction
    - Gradient reduction
  - Automated high quality seamless mosaics

I 2 R

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