



Practical Experience With Image Metrics for Aerial Products

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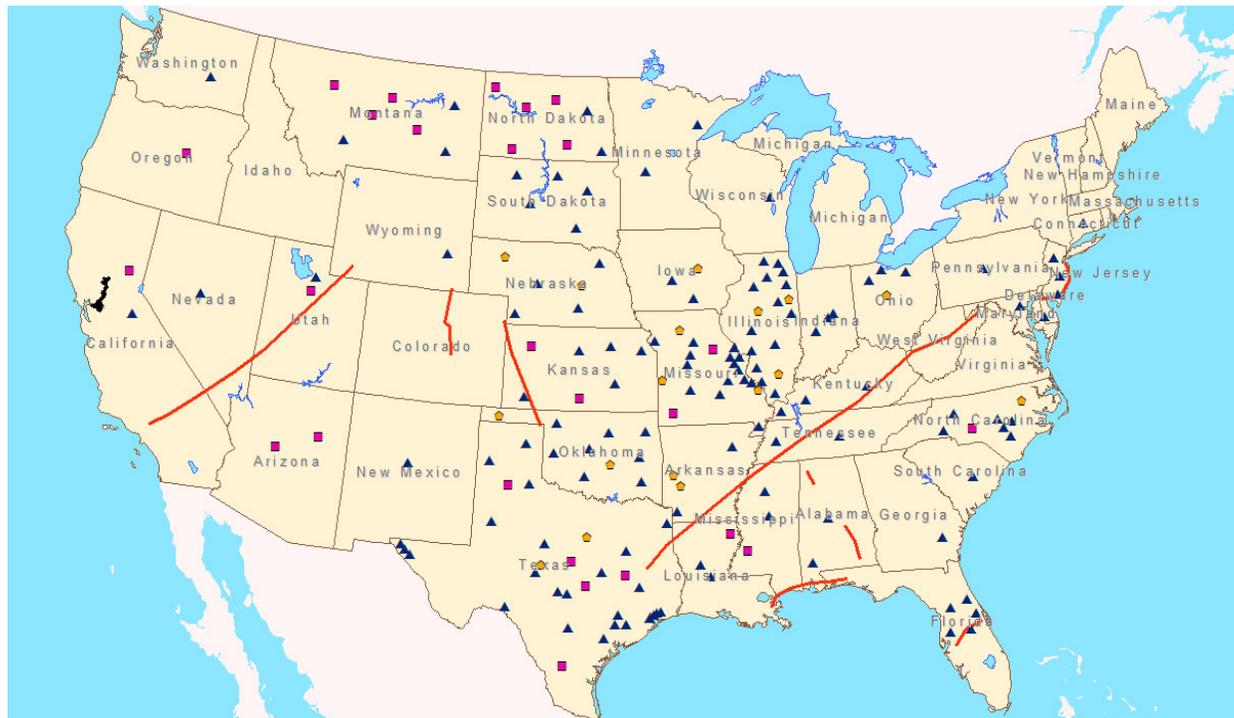
Surdex Corporation

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About Surdex Corporation



- Over one-half century in operation in St. Louis area
- 90+ employees
- Offices in St. Louis and Houston
- Clients throughout all of North America

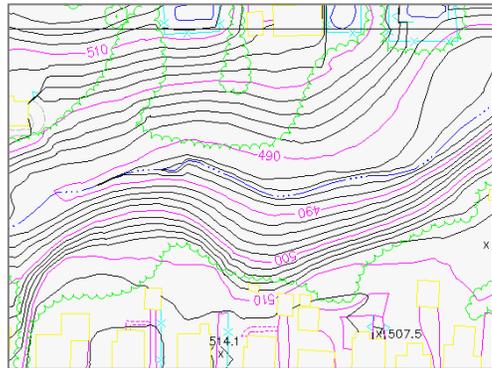


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Capabilities



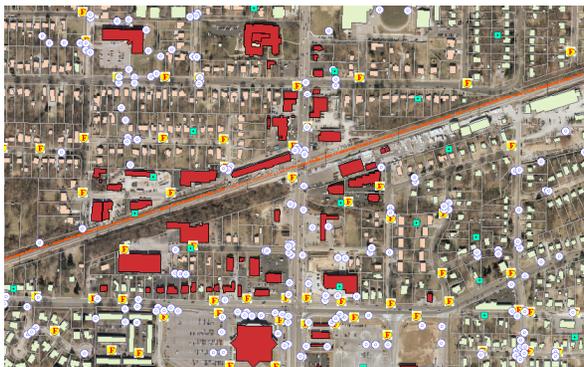
Planimetric



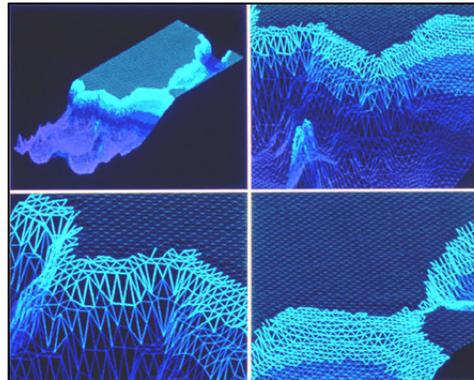
Contours



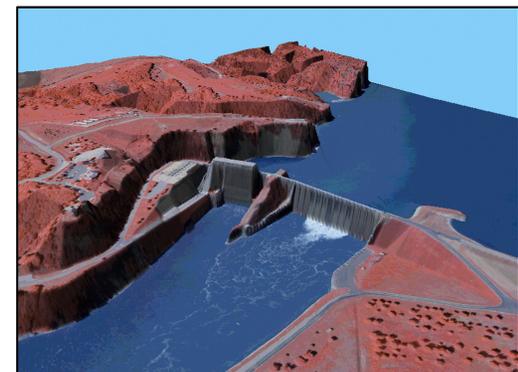
Digital Orthophotos



Planimetric



3D Surface



3D Models

Clients



- **State governments (DOT, DNR)**
- **County governments**
- **Municipal governments**
- **Federal (USDA, USGS)**
- **Defense mapping (NGA)**
- **Homeland/National Security**
- **U.S. Army Corps of Engineers**
- **Engineering and surveying companies**
- **Oil and gas exploration, gathering, transmission**

Context



- **Image metrics employed by the 2007 National Agriculture Imagery Program (NAIP)**
 - 1 or 2-meter resolution Digital Orthophoto Quarter Quadrangles (DOQQs)
 - Compressed County Mosaics (CCMs)
 - Film or digital imagery acquisition
- **First use of metrics by a civilian mapping program**
- **USDA Aerial Photography Field Office (APFO) studied image metrics**
 - Consulting agreement with ITT Space Systems
 - Interviews with field offices and contractors

NAIP Challenges



- **Imaging crops during peak growing season**
 - Short time period – as little as 40 days to capture 70,000 square miles
 - Humidity-induced haze
 - High-altitude acquisition for 1m: 30,000'+
 - Uncontrollable scene content – flooding, standing water, temporal changes
- **Extremely fast delivery of products to support Compliance analysis (<60 days after acquisition)**

NAIP Production Processing

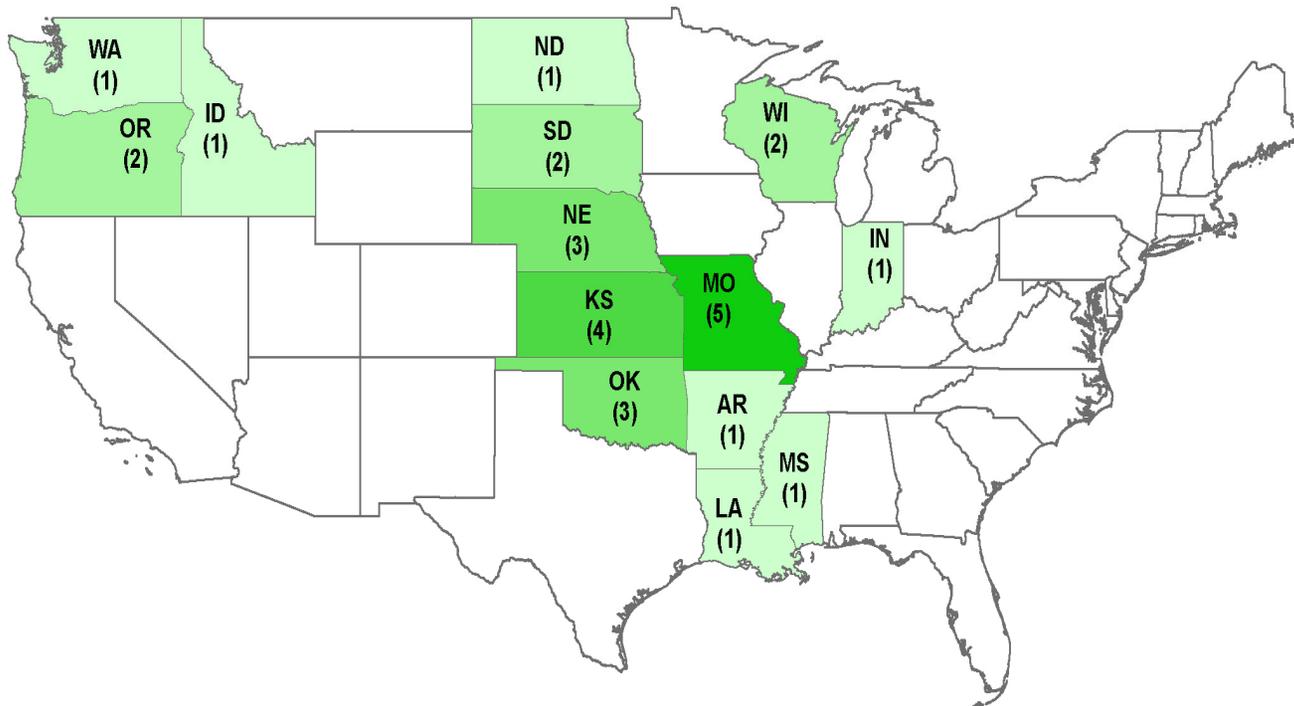


- **Incremental data deliveries required to meet schedules**
 - Cannot process entire state at once
 - Cannot control temporal context of data
 - Multiple scene types within a state
- **Use of a reference image to calibrate color, tone, balance a necessity before starting processing**

Surdex – 2003-2007 NAIP Projects



- 29 States over 5 years
- 140,000+ DOQQs
- ~2 million sq mi of 1 or 2-meter orthophotos
- Aerial film and digital imagery (Intergraph DMC) acquisition



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Metrics



3.2 Image Quality. All digital images shall have proper histograms and tone balance. Color imagery shall also have proper color balance and saturation.

- (a) Clipping. The DOQQs shall have a tonal range that prevents the clipping of highlight or shadow detail from the image. When calculated against the luminosity histogram, the cumulative pixel count between the first and last five histogram bin values (5 and 250 respectively for 8-bit depth) shall not be less than 98.0%, with a preferred value greater than 99%.**
- (b) Contrast. When calculated against the luminosity histogram, the difference between the histogram bin value that contains 99.0% of the cumulative pixel count and the value that contains 1.0% shall be greater than 120, with a preferred value of greater than 150. If the cumulative pixel count percentage falls between two histogram bin values, the close value shall be used. For example, if the luminosity value 222 contains 99% of the cumulative pixel count and value 44 contains 1% count, therefore the difference is 178.**
- (c) Histogram Peak. All DOQQs shall have a pixel count peak within $\pm 15\%$ of the middle digital value allowed for the bit depth. For example, an 8-bit depth image must have the histogram peak between 108 and 148.**
- (d) Color Balance. All DOQQs should have a neutral tonal range without the dominance of any individual color. The difference between the minimum and maximum value in a RGB triplet of any nearly neutral objects within the image shall be less than 10, with a preferred value less than 5.**

Metrics



- **Clipping**: ensuring tonal range that preserves shadow and highlight information
- **Contrast**: indicating complete use of 8 bit dynamic range
- **Histogram peak**: general brightness
- **Color balance**: measuring color balance consistency

Surdex Image Processing Approach



- **Inputs**
 - 12 bit direct digital
 - 12 bit scanned film
- **Goal - Best 8 bits**
 - 12 bit capture and 8 bit delivery: something must go
 - Mid tone preservation
- **Environment**
 - Calibrated displays – D65 standard, 2.2 Gamma
 - Subdued lighting – D65 standard

Surdex Image Processing Approach



- **Grouping Tool**

- Proprietary software developed by Surdex R&D
- Drive processing for thousands of images
- Front-end for color balancing, solar correction, digital dodging
- Retention of image statistics in Enterprise database
- Uses a reference image agreed upon with the USDA

- **Fully distributed processing environment**

- Up to 39 concurrent processors
- ~140TB of on-line storage
- Film or digital imagery acquisition

Grouping Tool



- **Grouping**
 - Images are exposed in groups with common aperture and shutter settings – sun angle and land cover change initiate new group
- **Gamma correction**
 - Raw digital images have linear distribution – the DN is proportional to the photons striking the pixel well
 - Humans and computer displays are logarithmic
 - A portion of the correction is achieved with gamma the remainder with LUT corrections to drive toward the target Histogram Peak range

Grouping Tool



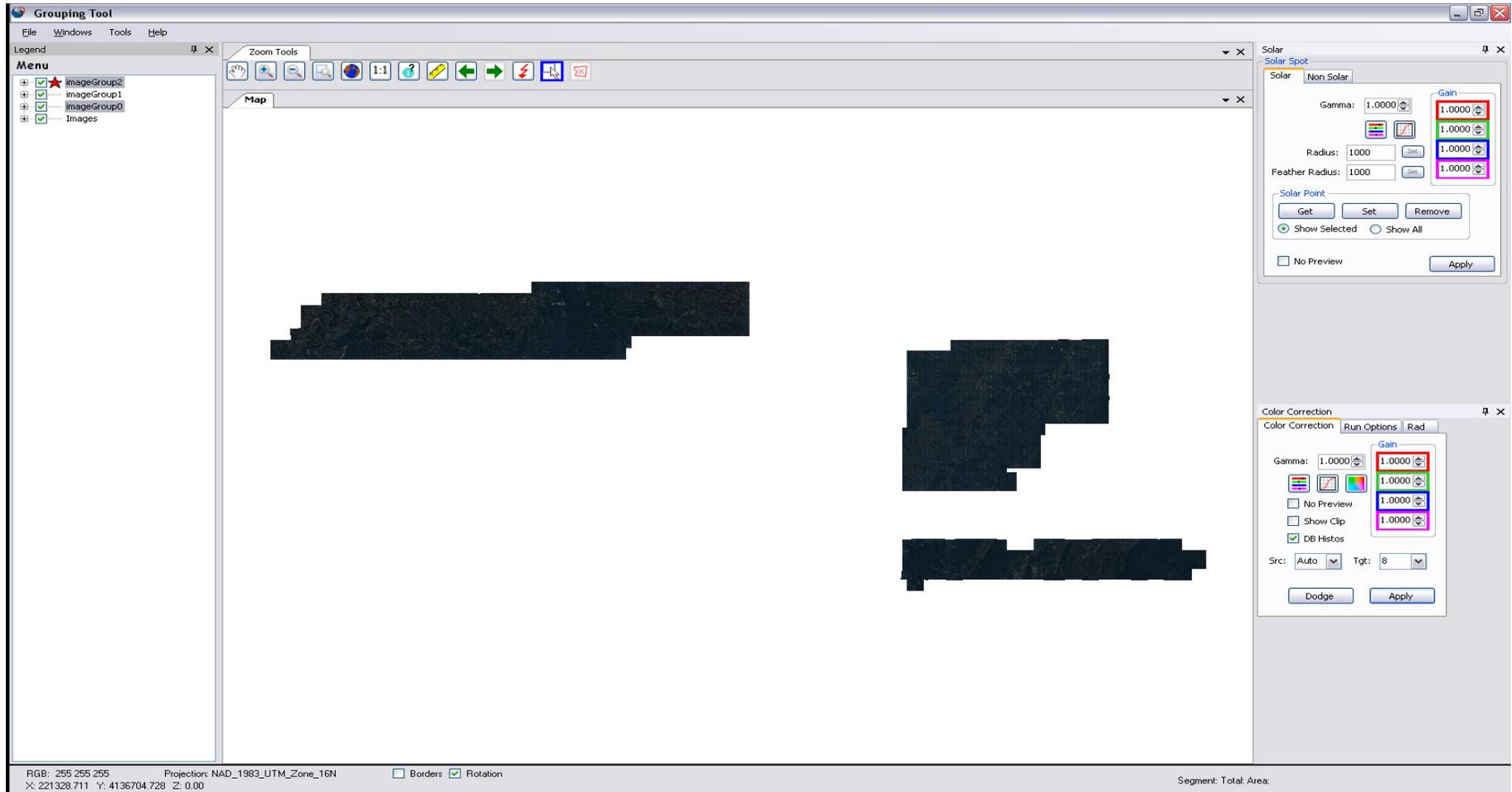
- **Solar**
 - Atmospheric correction – subtraction and multiplicative
 - Centered on ground position where solar illumination and camera view angle are coincident (“hot spot”)
 - Regional LUT developed
 - dark area subtraction
 - gain measurement
 - Mid tone color alignment

Grouping Tool



- **Dodge**
 - “Homogenizes” image brightness
 - BDRF - localized contrast correction
 - Cell-based correction following solar correction
 - LUT for each cell based on combination of linear stretch and histogram equalization

1019 Raw Images (>1TB) – TN, 2007



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Gamma Correction



The screenshot displays a GIS application window titled "Grouping Tool". The interface includes a menu on the left with a list of image files (e.g., 92-9_hr4.tif, 92-8_hr4.tif, etc.), a central map area showing a stepped terrain, and two panels on the right for gamma correction.

Solar Spot Panel:

- Gamma: 1.0000
- Radius: 1000
- Feather Radius: 1000
- Gain: 1.0000
- Buttons: Get, Set, Remove
- Radio buttons: Show Selected, Show All
- Checkbox: No Preview
- Button: Apply

Color Correction Panel:

- Gamma: 0.4000
- Gain: 1.0000
- Buttons: Dodge, Apply
- Checkbox: No Preview
- Checkbox: Show Clip
- Checkbox: DB Histos
- Dropdown: Src: Auto
- Dropdown: Tgt: 8

At the bottom of the window, the status bar shows: RGB: 16 32 42, Projection: NAD_1983_UTM_Zone_16N, Segment: Total Area.

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Solar Correction Point, Radius & Feather



The screenshot displays the Grouping Tool software interface. The main window shows a map of an urban area with a red circle and a central red dot representing a solar correction point. A large light blue arc is drawn on the right side of the map. The interface includes a menu on the left with a list of files (e.g., 92-41_hr4.tif), a legend, zoom tools, and a status bar at the bottom showing coordinates and projection information.

Solar Spot Panel:

- Gamma: 1.0000
- Radius: 1000
- Feather Radius: 9552.1847
- Gain: 1.0000 (with color bars)
- Buttons: Get, Set, Remove
- Options: Show Selected (checked), Show All
- Checkbox: No Preview
- Button: Apply

Color Correction Panel:

- Gamma: 0.4000
- Gain: 1.0000 (with color bars)
- Options: No Preview, Show Clip, DB Histos (checked)
- Src: Auto, Tgt: B
- Buttons: Dodge, Apply

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Solar Correction Point, Radius & Feather



The screenshot displays a GIS application window titled "Grouping Tool". The main map area shows an aerial photograph of a city with a red circle and a central red dot overlaid. A blue arc is drawn on the right side of the map, extending from the red dot towards the right edge. On the left, a legend lists numerous files with names like "92-41_hr4.tif" through "91-46_hr4.tif". On the right, there are two control panels:

- Solar Spot Panel:** Contains settings for Gamma (1.0000), Radius (1000), and Feather Radius (9552.1847). It also has a "Gain" section with three sliders set to 1.0000, and buttons for "Get", "Set", "Remove", "Show Selected", "Show All", and "Apply".
- Color Correction Panel:** Contains settings for Gamma (0.4000) and Gain (1.0000). It includes checkboxes for "No Preview", "Show Clip", and "DB Histos", and dropdowns for "Src" (Auto) and "Tgt" (8). It has "Dodge" and "Apply" buttons.

At the bottom of the window, there is a status bar with the following information: RGB: 255 255 255, Projection: NAD_1983_UTM_Zone_16N, Segment: Total Area, and coordinates X: 671230.502, Y: 3884407.190, Z: 0.00.

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Gain Measurements on Neutrals



Grouping Tool

File Windows Tools Help

Legend Gain

ID	Red	Green	Blue	Dev
1	162.368...	173.736...	175.421...	5.8
2	156.0625	170.6875	176.0625	8.45
3	143.684...	154.421...	156.789...	5.7
4	196.791...	208.25	202.333...	4.68
5	155.595...	165.951...	167.468...	5.26
6	106.6	120.6	123.6	10.63

Gain

1.09 1.000 0.968

Red Green Blue

Apply Cancel Ok

92-25_hr4.tif
92-24_hr4.tif
92-23_hr4.tif
92-22_hr4.tif
92-21_hr4.tif
92-20_hr4.tif
92-19_hr4.tif
92-18_hr4.tif
92-17_hr4.tif
92-16_hr4.tif
92-15_hr4.tif
92-14_hr4.tif
92-13_hr4.tif
92-12_hr4.tif
92-11_hr4.tif
92-10_hr4.tif
91-9_hr4.tif
91-8_hr4.tif
91-7_hr4.tif
91-6_hr4.tif
91-61_hr4.tif
91-60_hr4.tif
91-5_hr4.tif
91-59_hr4.tif
91-58_hr4.tif
91-57_hr4.tif
91-56_hr4.tif
91-55_hr4.tif
91-54_hr4.tif
91-53_hr4.tif
91-52_hr4.tif
91-51_hr4.tif
91-50_hr4.tif
91-4_hr4.tif
91-49_hr4.tif
91-48_hr4.tif
91-47_hr4.tif
91-46_hr4.tif

RGB: 115 127 133 Projection: NAD_1983_UTM_Zone_16N
X: 662999.679 Y: 3881578.434 Z: 115.00

Segment: Total Area

Solar Spot

Solar Non Solar

Gamma: 1.0000 Gain 1.0900
1.0000
0.9680
1.0000

Radius: 1000
Feather Radius: 9552.1847

Solar Point
Get Set Remove
Show Selected Show All

No Preview Apply

Color Correction

Color Correction Run Options Rad

Gamma: 0.4000 Gain 1.0000
1.0000
1.0000
1.0000

No Preview Show Clip DB Histo

Src: Auto Tgt: 8
Dodge Apply

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Color & CIR Views



The image displays a series of software interface elements for remote sensing data processing. On the left, a 'Histograms' window shows four histograms: black, red, green, and blue, each with a corresponding color bar and a list of values. The histograms are plotted against a range from 0 to 255. The central and right portions of the image show a 'Solar Spot' panel with settings for Gamma (1.0000), Radius (1000), and Feather Radius (9552.194). Below this is a 'Color Correction' panel with similar settings. The main area features two sets of aerial imagery. The top set shows a color view of an industrial area with a lake, and the bottom set shows the same area in CIR (Color Infrared) view, where vegetation is highlighted in red. The bottom right corner includes a 'Segment: Total Area' label.

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Balancing to Metrics



Grouping Tool

File Windows Tools Help

Legend

Menu

- imageGroup0
- Images

Zoom Tools

Map

Color Correction

Color Correction Run Options Rad

Gain

Gamma: 1.0000 1.0000 1.0000 1.0000

No Preview Show Clip DB Histos

Src: Auto Tgt: 8

Dodge Apply

Solar

Solar Spot

Solar Non Solar

Gamma: 1.0000 1.0000 1.0000 1.0000

Radius: 1000 Feather Radius: 1000

Solar Point

Get Set Remove

Show Selected Show All

No Preview Apply

RGB: 255 255 255 Projection: NAD_1983_UTM_Zone_16N

X: 611322.022 Y: 3971501.518 Z: 0.00

Borders Rotation

Segment: Total Area

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Dodge (DMC Image, KS 2006)



Original



First Pass



Final Pass



Missouri, 2007 (Film Acquisition)



~5,000 DOQQs
115 Counties



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Image Metrics (MO, 2007)



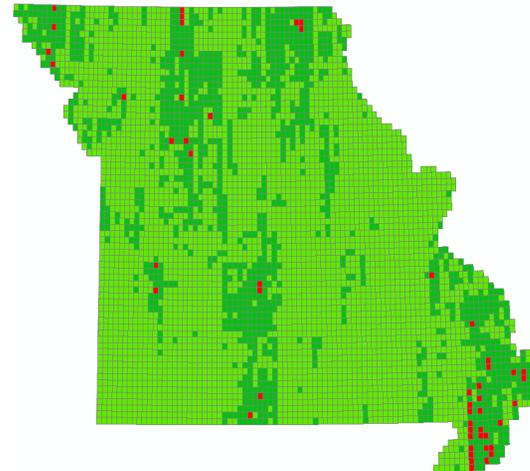
Clipping

99% of data within 5 and 250



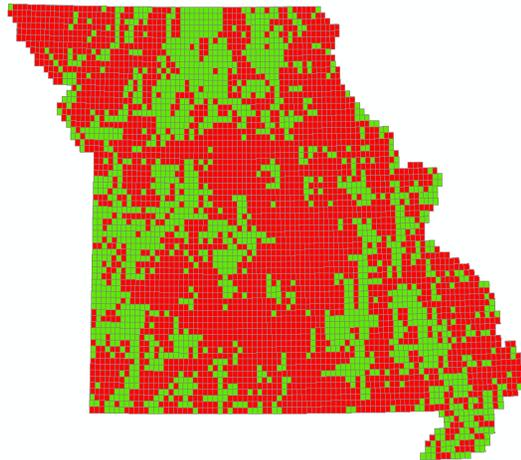
Contrast

- Below 120
- 120 to 140
- Above 140



Histogram Peak

- Below 108
- 108 to 140
- Above 140



Color Balance

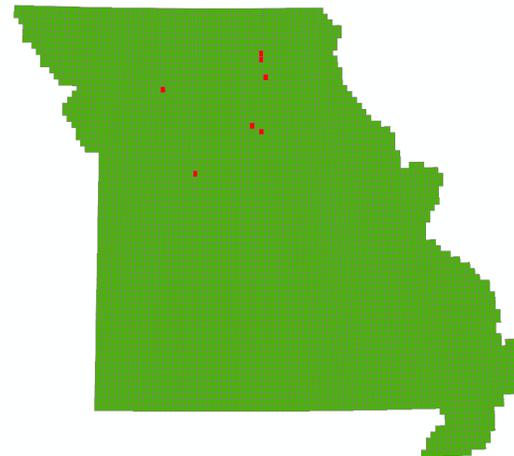
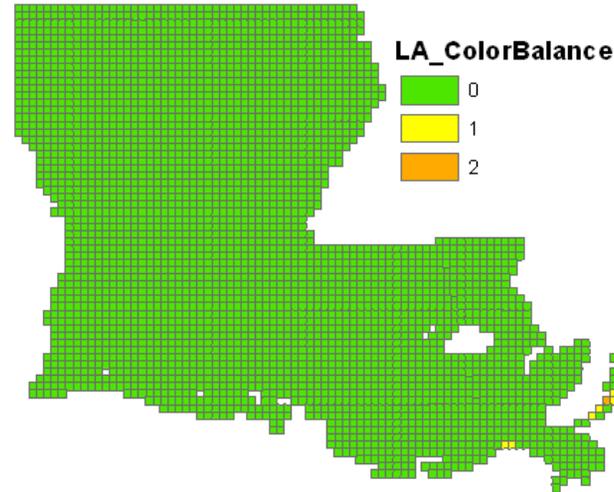
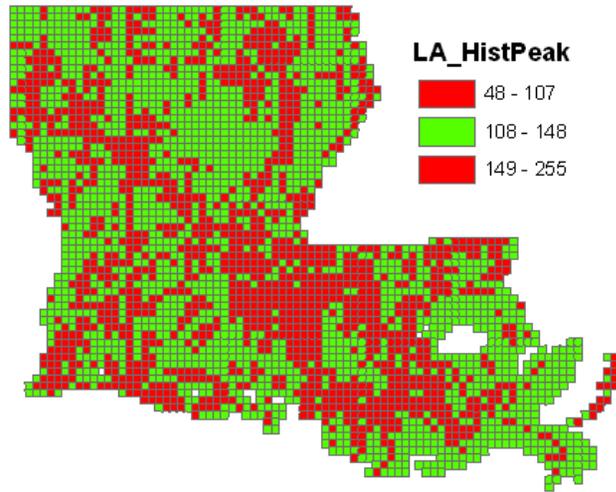
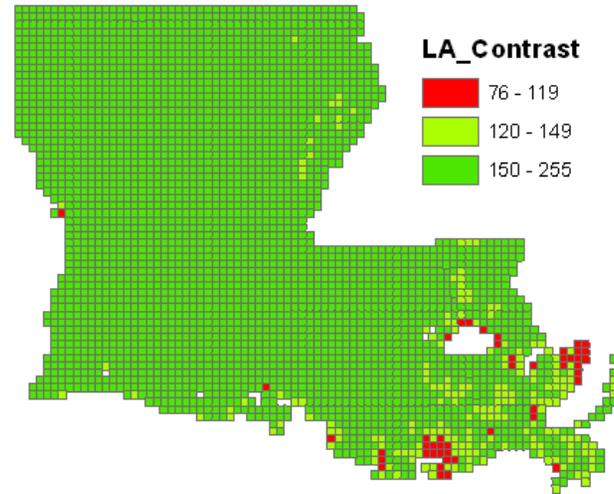
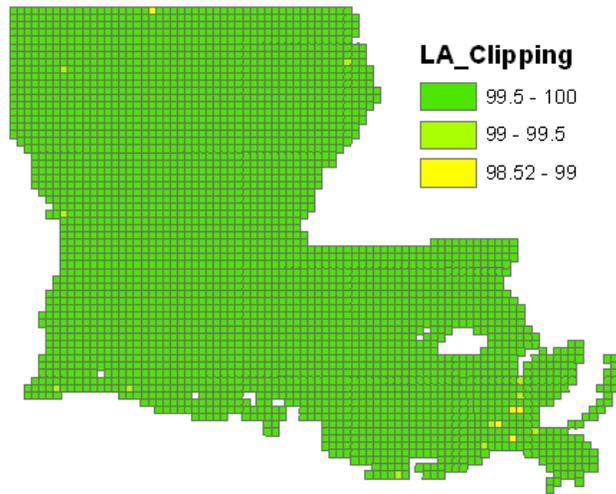


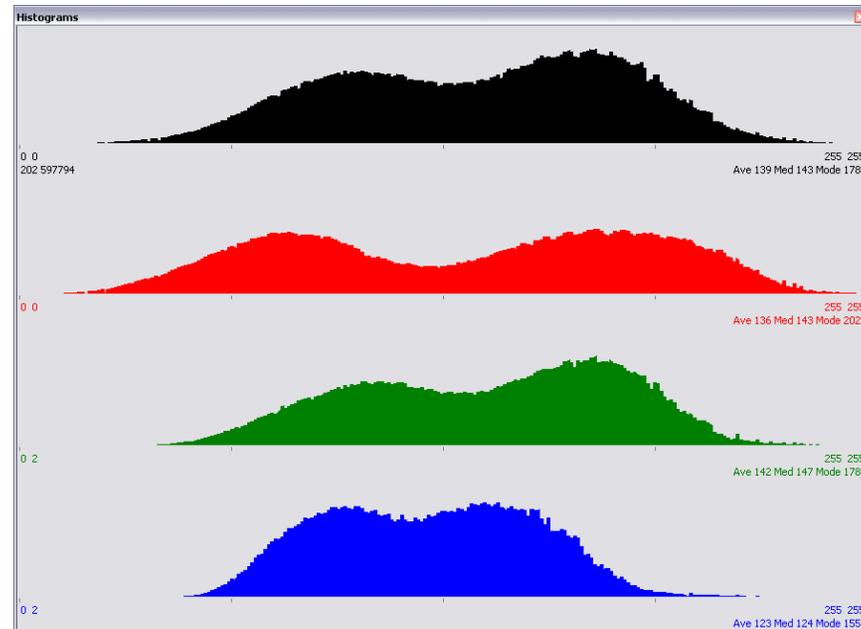
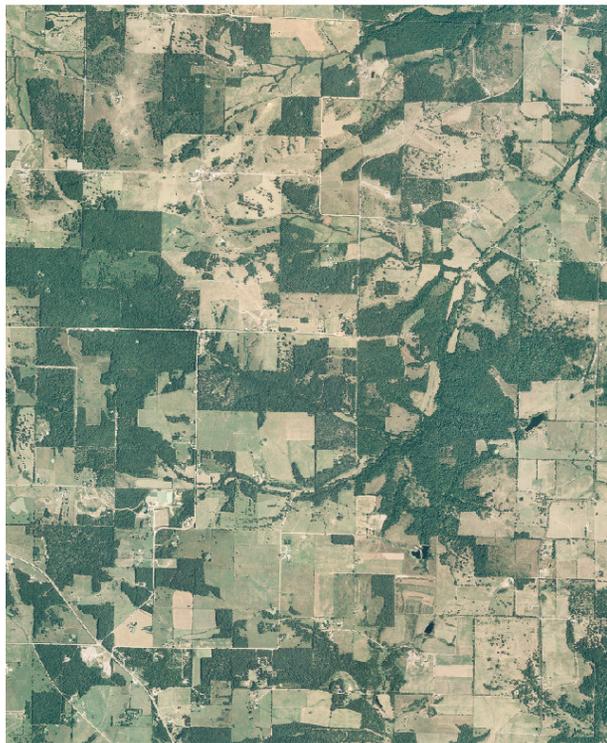
Image Metrics (LA, 2007)



What's Up With Histogram Peak?



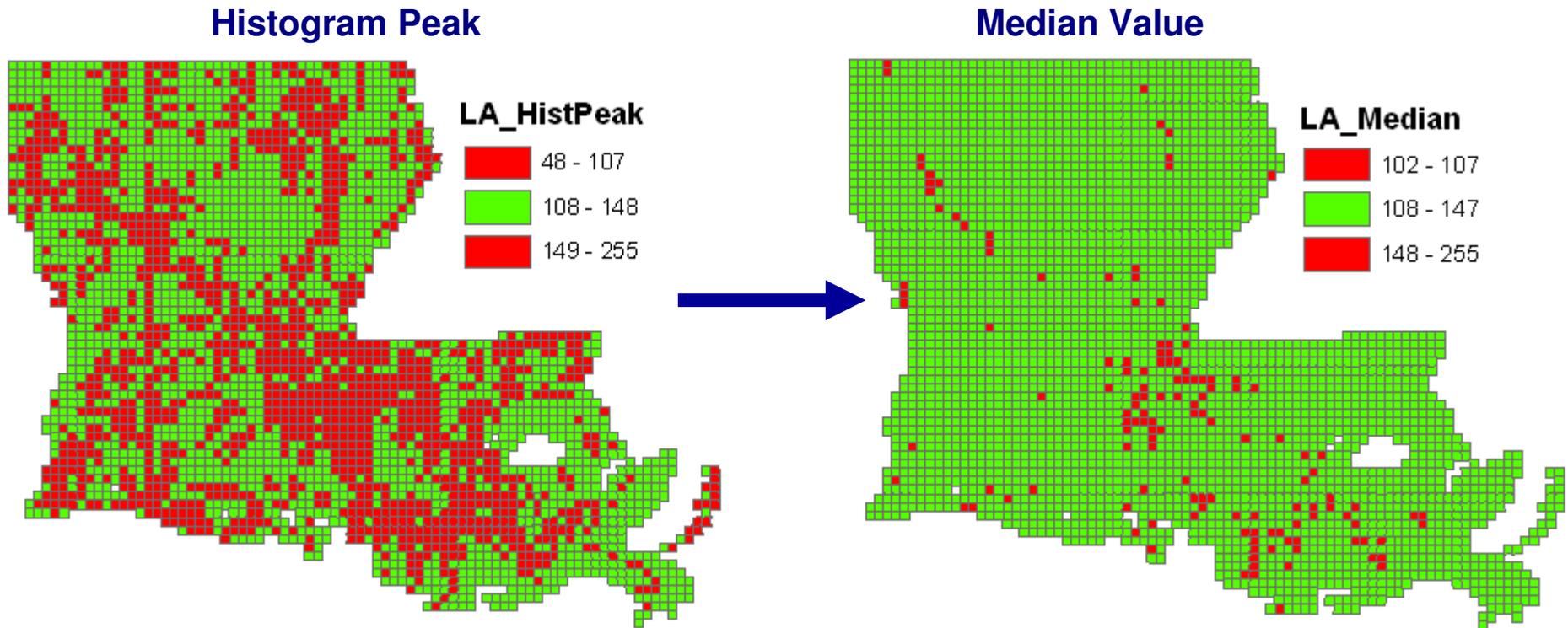
- **Bi-modal example...basis of numerous failures!**
- **Image products are (subjectively) very acceptable**



Median Vice Histogram Peak



- Replacing histogram peak with equivalent metrics based on median value....



4-Band Products...

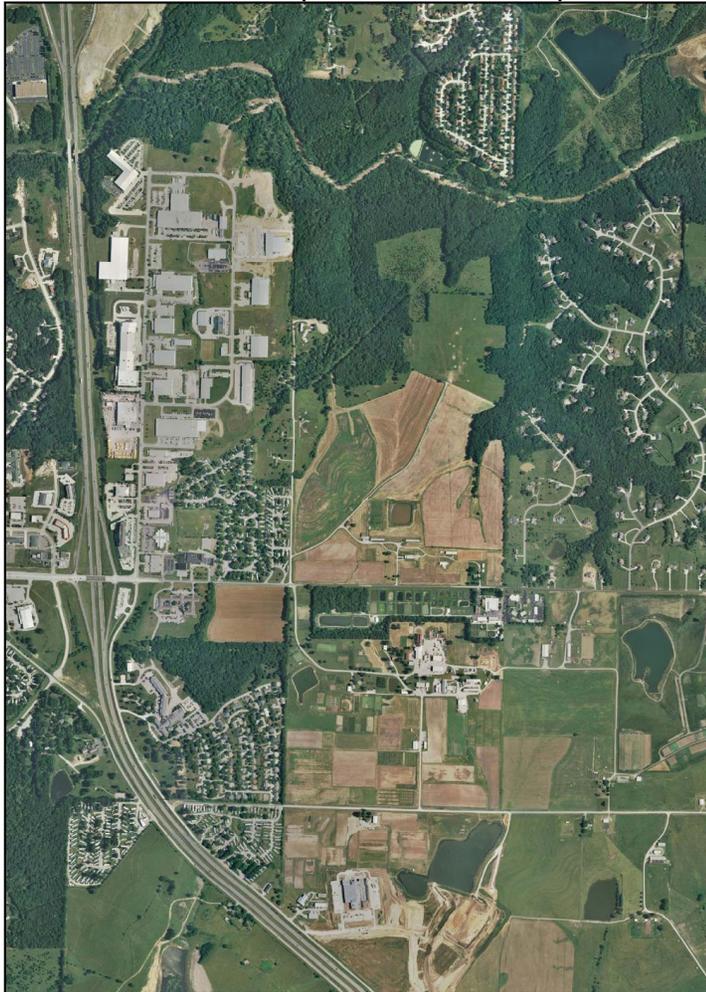


- **4-band products**
 - R,G,B,NIR bands
 - More commonly required by the NAIP
 - Becoming more common for all clients
- **Surdex's approach**
 - Work RGB as in standard approach, including metrics
 - Separately handle NIR band
 - RGB and NIR must be very close to final solution, or balancing software (OrthoVista) will disturb all 4 bands

4-Band Data...6" Resolution



R,G,B (bands 1,2,3)



NIR,R,G (bands 4,1,2)



Future Enhancements



- **Absolute model based correction**
 - BDRF
 - Inverse hill-shade
 - Molecular and aerosol atmospheric optical depth models – based on MODIS?
 - Heuristically - statistics from manual optimization used to seed correction

Summary Remarks...



- **Image metrics provide great benefits**
 - Client benefits from objective measures and consistency between contractors
 - Contractors benefit from reduced re-work
 - Need further experience and refinement
 - 4-band metrics? CIR difficult to agree upon
- **Surdex's 2008-2010 State of Missouri contract requires image metrics (2', 1', 6" and 3" GSD)**
 - Leaf-off will likely require "tweaking" of metrics
- **Self-levied metrics for Albuquerque and Denver COG (Council of Governments) for 2008**