Preprocessing of P6-AWiFS for Field Level Data Extraction and Data Mining

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USDA RMA
Risk Management Agency

About the Risk Management Agency

- role is to help producers manage their business risks through effective, market-based risk management solutions
- promote, support, and regulate sound risk management solutions to preserve and strengthen the economic stability of America's agricultural producers
- operates and manages the Federal Crop Insurance Corporation (FCIC)
- provides crop insurance to American producers through 16 private-sector insurance companies sell and service the policies.

FY 2005 Program Size

Number of Policies …….. 1.19 million
Premium Volume …….. $3.95 billion
Crop Value Insured …….. $44.29 billion*
Acres Insured ……..…. 246 million
Data accurate as of January 16, 2006

- RMA develops and/or approves the premium rate, administers premium and expense subsidy, approves and supports products, and reinsures the 16 companies
- sponsors educational and outreach programs and seminars on the general topic of risk management

Purpose & Goal

- take the best pieces of the scientific work done on AWiFS by ANTRIX, USDA, USGS, NASA, and GeoEye for operational agency use
- RMA/SDAA has an extensive KDD/Data Mining operation used to analyze patterns in crop insurance policies for increasing program integrity
  - Center for Agribusiness Excellence; Tarlton State University; Stephenville, TX
- the purpose is to develop automated / semi-automated procedures to incorporate moderate resolution satellite imagery into the KDD/Data Mining process
- the goal is to be able to provide field-level metrics throughout the growing season on crop health

Process

- develop automated / semi-automated procedures to preprocess IRS AWiFS (and other satellite data)
  - preprocessed to Top-of-Atmosphere-Reflectance (TOA) or *% reflectance*
    - no correction for atmospheric scattering or absorption, atmospheric gases (water vapor and ozone) and aerosols
  - TOA selected because it is a quick, low/no cost implementation with little other inputs needed & can work within our environment

Process, cont.

- after AWiFS is preprocessed, extract data for each unique field
  - field information: USDA FSA Common Land Unit (CLU)
  - constrains: size (given each AWiFS pixel is approximately 0.70 acres), shape of field
  - data table by day of year for NDVI, NDWI, LSWI with mean & variance measure captured for each field
- data in 8-bit format, rather than 10-bit
- **orthorectified data usually available to RMA from USDA Satellite Image Archive within 1 day (at most, 2 days) after acquisition**

Preprocessing Implementation

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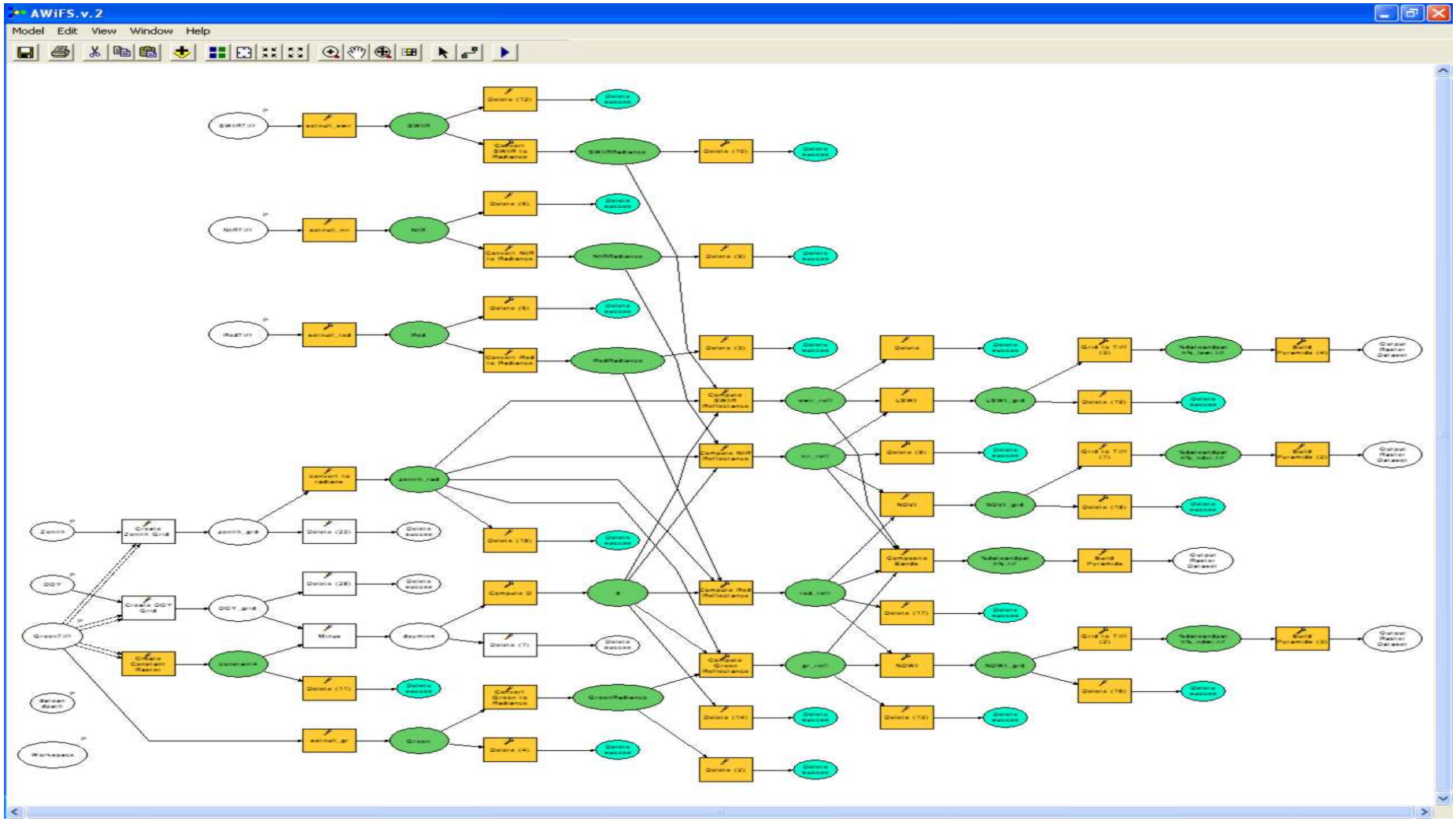
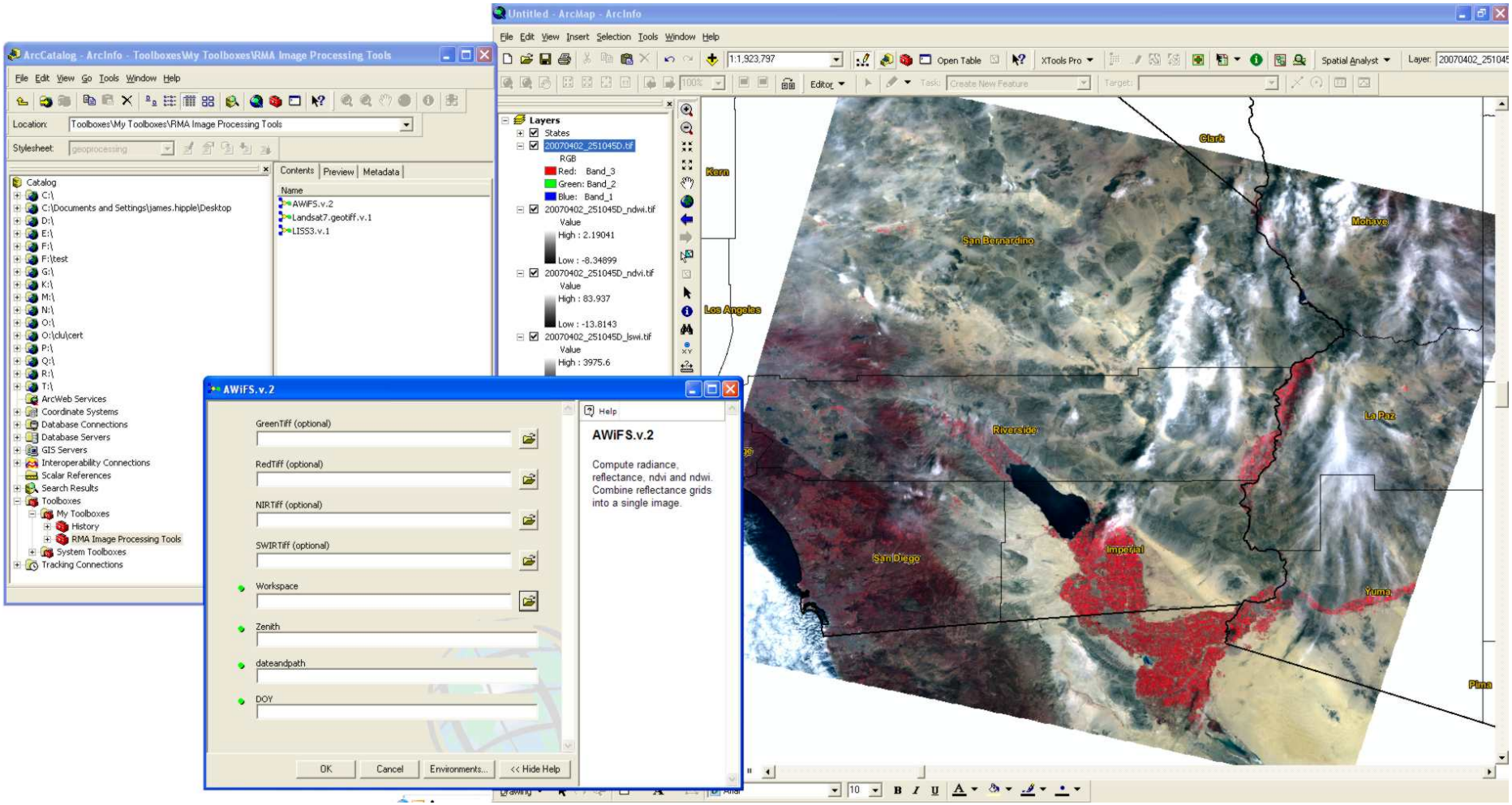
Preprocessing Implementation

- developed in ESRI ArcCatalog ModelBuilder
- straightforward processing
- model could be used across USDA
  - ArcGIS on almost every desktop
  - COTS image processing software ENVI, Erdas Imagine, ER Mapper, etc. highly varied
- distributed as a ToolBox
  - developed for AWiFS geotiff, but is being adapted for Landsat 7 ETM+ geotiff, Landsat 7 ETM+ geotiff , IRS ResourceSat LISS-3 geotiff

Model Builder Preprocessing ToolBox



Process and Results



DN to Radiance to Reflectance

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DN to Radiance Step

- NASA SSC derived calibrations $Q_{calDN(\lambda)}$:
- the following 2006 derived values were used
  - Green Radiance = $DN_{10} * (0.60) + (-5.49)$
    $= DN_8 * (2.367) + (-24.311)$
  - Red Radiance = $DN_{10} * (0.49) + (-1.55)$
    $= DN_8 * (1.96) + (-6.281)$
  - NIR Radiance = $DN_{10} * (0.32) + (-2.38)$
    $= DN_8 * (1.284) + (-9.548)$
  - SWIR Radiance = $DN_{10} * (0.063) + (-2.88)$
    $= DN_8 * (0.253) + (-11.55)$

From: M. Pagnutti. Initial Radiometric Calibration of the AWiFS using Vicarious Calibration Techniques. *USDA FAS/PECAD Seminar*. September 12, 2006., and M. Pagnutti & K. Holekamp. Radiometric Calibration of the AWiFS using Vicarious Calibration Techniques. *JACIE Civil Commercial Imagery Evaluation Workshop*. March 21, 2007.

Radiance to Reflectance Step

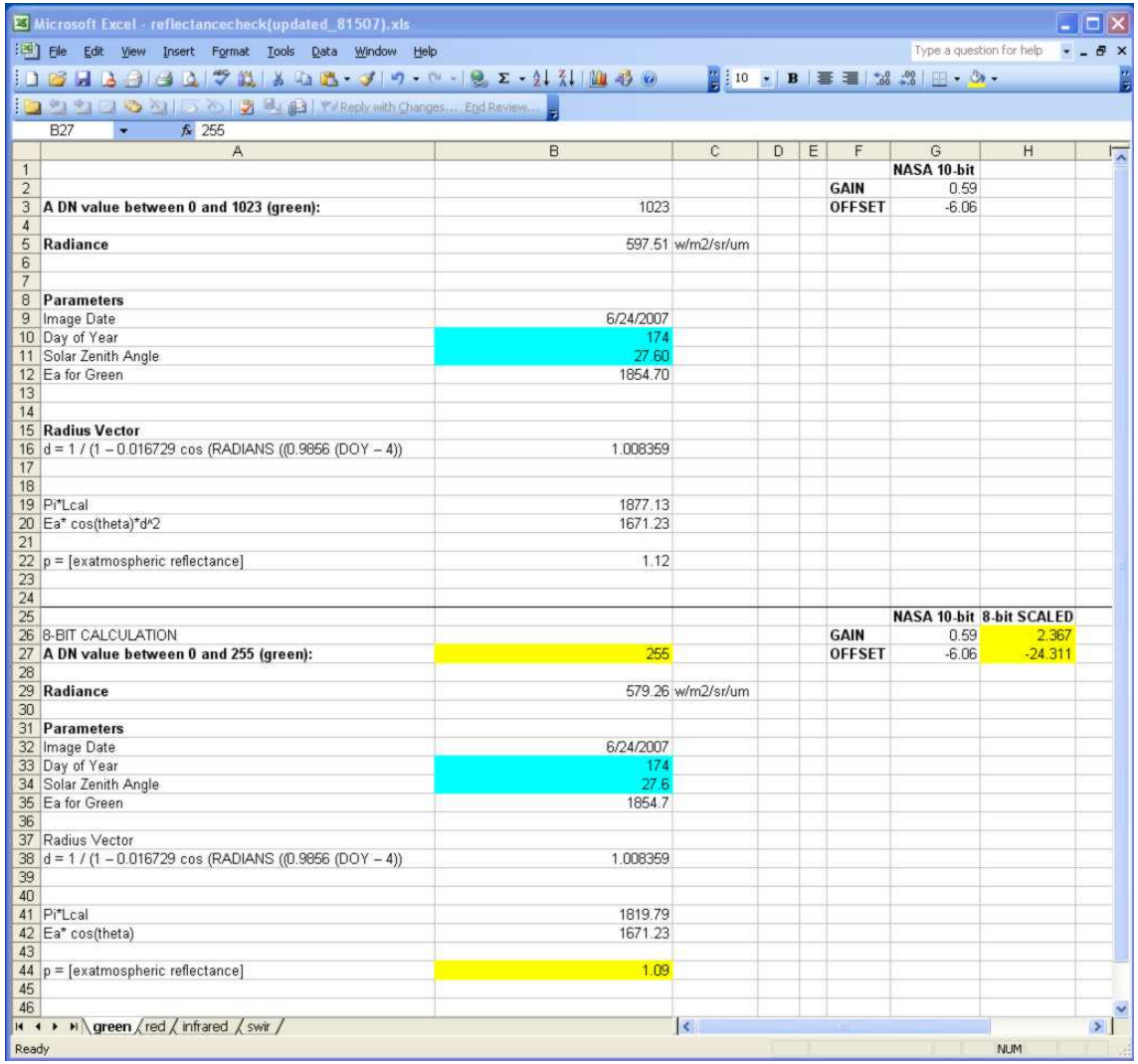
- $\rho = (L_{cal(\lambda)}/d^2)\ E_{a(\lambda)} \cos \theta_a$
  - ρ : percent reflectance
  - $L_{cal(\lambda)}$: TOA radiance for a particular wavelength (band)
  - $E_{a(\lambda)}$: sensor solar exoatmospheric irradiance in (W m^{-2} μm^{-1}) for a particular wavelength (band)
  - d : radius vector
    - ratio of mean sun-earth distance
    - *d = 1 / (1 – 0.016729 cos (0.9856 (DOY – 4)*
      [d = 1 / (1 – 0.016729 cos (RADIANS ((0.9856 (DOY – 4))]
    - DOY = 1 to 365/366
  - θ_a : solar zenith angle (extracted from geotiff header) radius vector

- Parameter: $E_a(\lambda)$ sensor solar exoatmospheric irradiance in (W m^{-2} μm^{-1})
  - B2: 1849.5 W m^{-2} μm^{-1}
  - B3: 1553.0 W m^{-2} μm^{-1}
  - B4: 1092.0 W m^{-2} μm^{-1}
  - B5: 239.52 W m^{-2} μm^{-1}

From: M.R. Pandya et al, *IEEE Transactions on Geoscience and Remote Sensing*, vol. 40, No. 3, pp.714-718, 2002.

Quality Control of Model Builder Results

- equations verified in MS Excel
- calculated 10-bit and 8-bit values
- effects of ‘binning’ to 8-bit from 10-bit can be seen in radiance & reflectance values
- served as an ‘validation check’ of randomly selected pixels in the ESRI ModelBuilder



Microsoft Excel - reflectancecheck(updated_81507).xls

File Edit View Insert Format Tools Data Window Help

B27 = 255

	A	B	C	F	G	H
1					NASA 10-bit	
2				GAIN	0.59	
3	**A DN value between 0 and 1023 (green):**	1023		OFFSET	-6.06	
4						
5	**Radiance**	597.51	w/m2/sr/um			
6						
7						
8	**Parameters**					
9	Image Date	6/24/2007				
10	Day of Year	174				
11	Solar Zenith Angle	27.60				
12	Ea for Green	1854.70				
13						
14						
15	**Radius Vector**					
16	d = 1 / (1 – 0.016729 cos (RADIANS ((0.9856 (DOY – 4))	1.008359				
17						
18						
19	Pi*Lcal	1877.13				
20	Ea* cos(theta)*d^2	1671.23				
21						
22	p = [exatmospheric reflectance]	1.12				
23						
24						
25					NASA 10-bit	8-bit SCALED
26	8-BIT CALCULATION			GAIN	0.59	2.367
27	**A DN value between 0 and 255 (green):**	255		OFFSET	-6.06	-24.311
28						
29	**Radiance**	579.26	w/m2/sr/um			
30						
31	**Parameters**					
32	Image Date	6/24/2007				
33	Day of Year	174				
34	Solar Zenith Angle	27.6				
35	Ea for Green	1854.7				
36						
37	Radius Vector					
38	d = 1 / (1 – 0.016729 cos (RADIANS ((0.9856 (DOY – 4))	1.008359				
39						
40						
41	Pi*Lcal	1819.79				
42	Ea* cos(theta)	1671.23				
43						
44	p = [exatmospheric reflectance]	1.09				
45						
46						

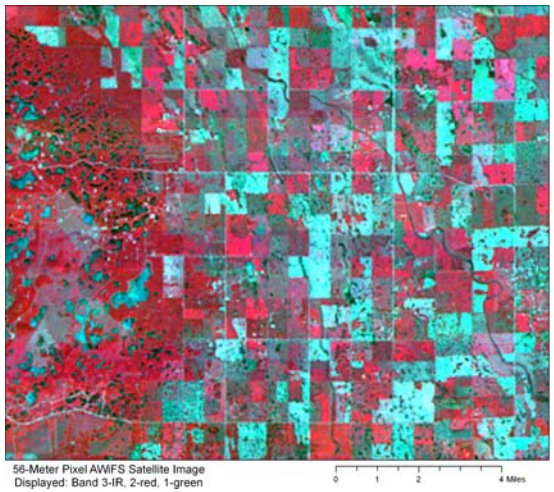
green / red / infrared / swir /

Ready NUM

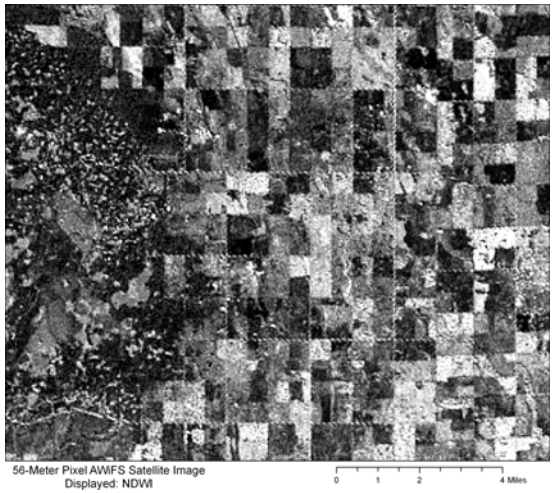
Naming Conventions

- pull from CDINFO (or CDINFO.txt) (structure of data of the downloaded AWiFS)
- process names the files in this manner:
  - yyyymmdd_ppprrrqxxxx.tif
    - yyyy = year
    - mm = month
    - dd = day
    - ppp = path
    - rrr = row
    - q = quad (A, B, C, D)
    - xxxx = index type (ndvi, ndwi, lswi)
- example: 2007518_263040b.tif; 2007518_263040b(ndvi).tif; 2007518_263040(ndwi).tif

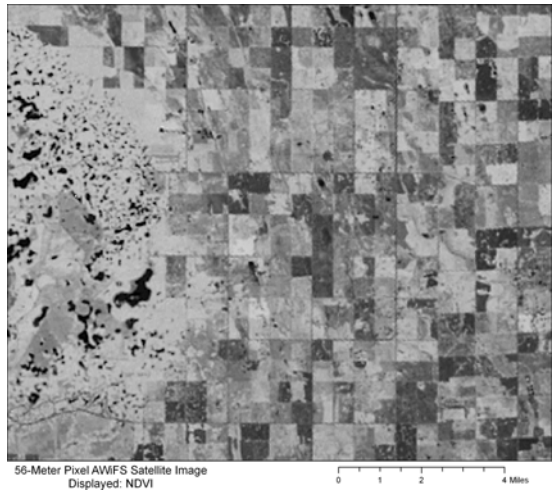
Derived Products



4-band layer-stacked geotiff in
% reflectance with pyramids built



Normalized Difference Water Index



Normalized Difference Vegetation Index

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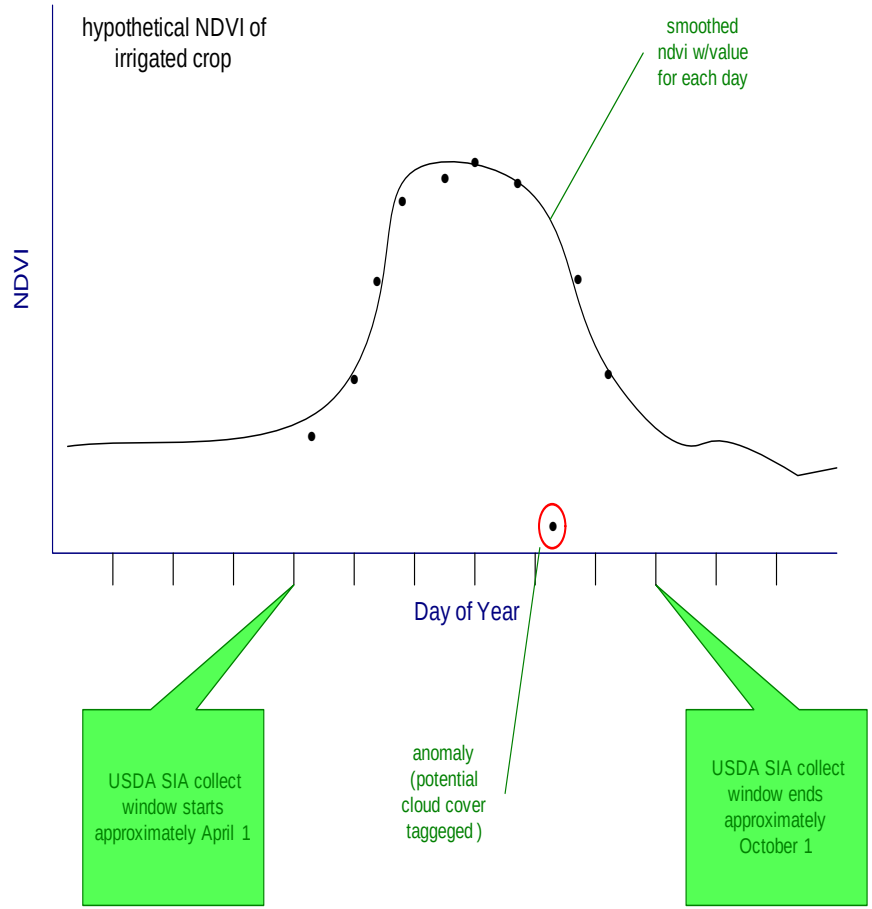
Land Surface Water Index (LSWI)

Indices Generated

- calculate vegetation index
  - ND**V**I (Normalized Difference Vegetative Index)
    - NDVI = (nir – red)/ (nir + red)
- calculate water index
  - ND**W**I (Normalized Difference Water Index)
    - NDWI = (red – green) / (red + green)
- calculate land surface water irrigated / non-irrigated differentiator
  - LSWI (Land Surface Water Index)
    - LSWI = (nir – swir)/ (nir + swir)



Status

- ModelBuilder complete for AWiFS & LISS
- under development for Landsat 7 ETM+ geotiff and Landsat 7 ETM+ geotiff
- 80% of 2007 US scenes AWiFS scenes processed (by West Virginia University National Geospatial Development Center / NRCS under CREDA)
- 2006 US scenes being copied by USDA SIA & will be turned over to West Virginia University National Geospatial Development Center / NRCS for processing
- single AWiFS scene takes 15 minutes to process (requires user input), working on automating the ModelBuilder so images can be batched

Extraction of Field Level Metrics (development ongoing)

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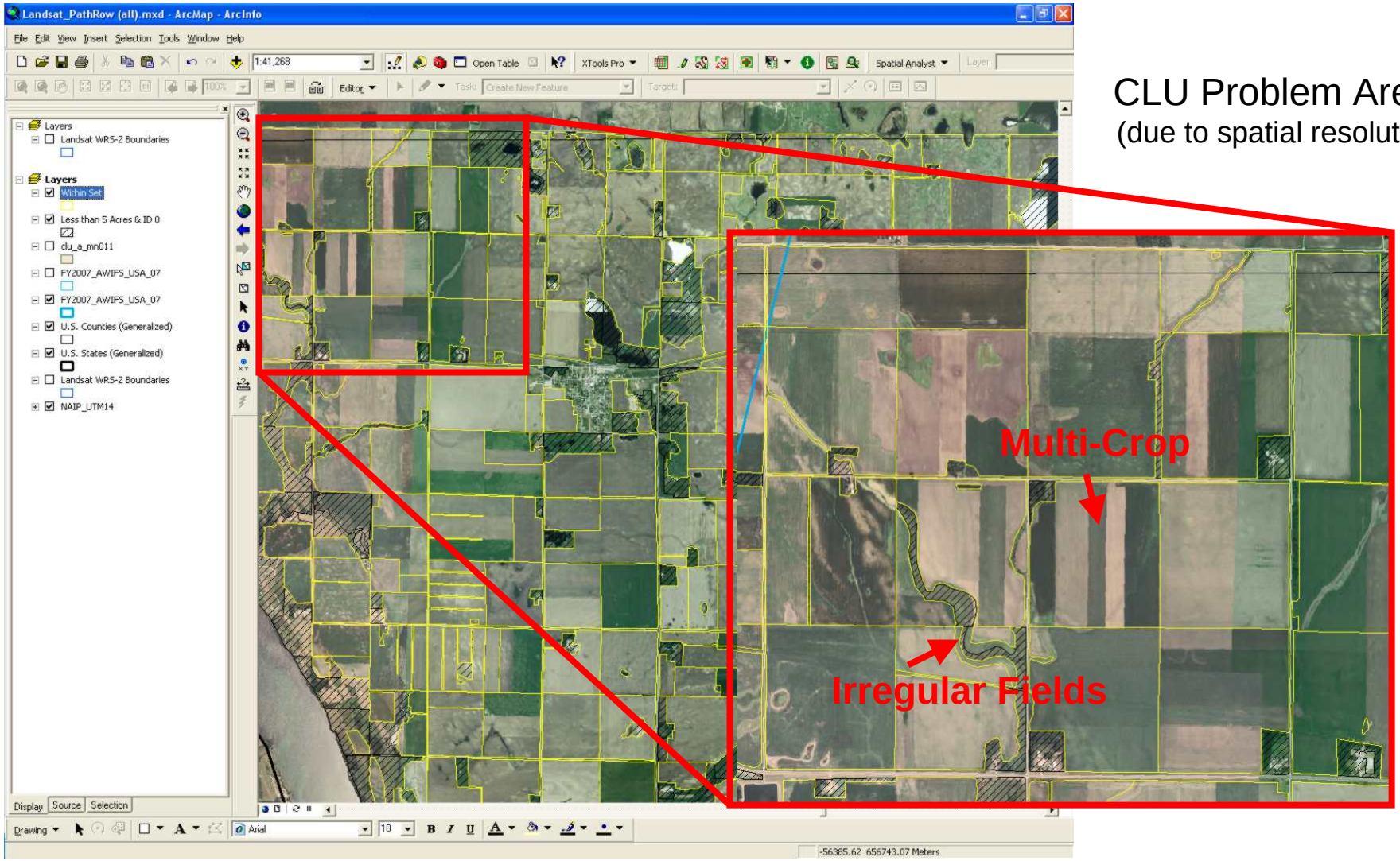
CLU and Field Selection



CLU Problem Areas
(due to spatial resolution)

Metric Extraction & Future Direction

- working on the metric extraction procedure
  - select CLU that meet criteria of minimum size, shape
  - select CLU set that is within new image AWiFS footprint
  - calculate mean & variance values for indices & spectral bands for pixels within field boundary
  - develop ‘running’ smoothing procedure to fill in gaps
  - try to do this real-time or near real time
- look at near real time classification of crop-type cover on a per field basis
  - validate 2006 & 2007 with NASS Cropland Data Layer

Thanks To …

- West Virginia University National Geospatial Development Center / NRCS (Jim Thompson, Henry Ferguson & Amanda Moore) for assistance on the AWiFS processing
- Bob Tetrault & Brad Doorn for assisting in streamlining data delivery through the USDA SIA
- the staff at ASRC, Global Marketing Insights, Inc. for putting together this forum

Questions …

- Dr. Jim Hipple, USDA Risk Management Agency

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