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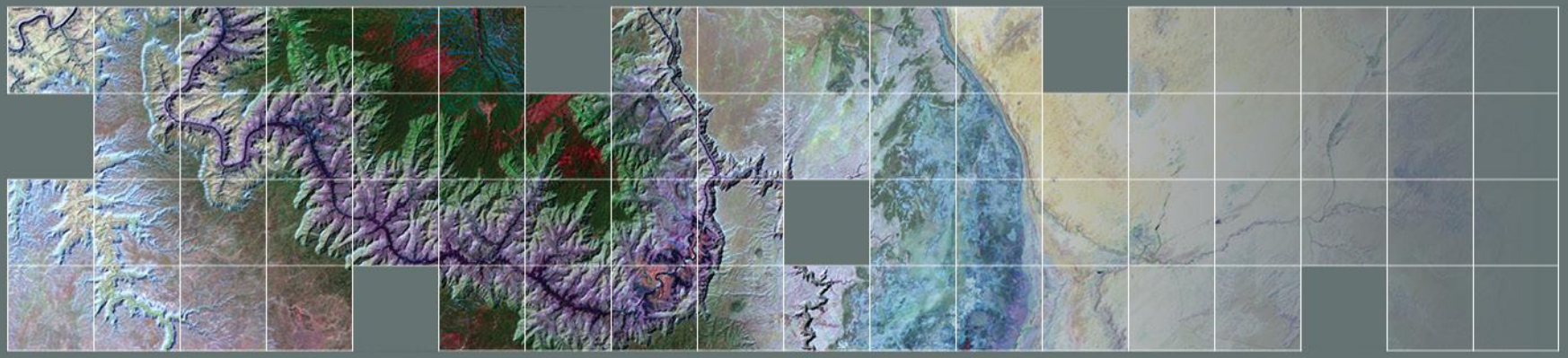
science for a changing world

Climate and Land Use Change
Earth Resources Observation and Science (EROS) Center

Landsat Science Products: Current Status and Future Planned



John Dwyer USGS EROS Center
Landsat Science Team Meeting
December 13, 2012

U.S. Department of the Interior
U.S. Geological Survey

Landsat 1-7 Product Evolution

- **Improve registration**
  - Increase percentage of L1T
  - Ground Control Point (GCP) analysis – seasonal, historical, stable
  - GCP outlier rejection
  - Independent verification of geometry
  - Fallback to L1Gt instead of L1G for ETM+
- **Improve radiometry**
  - Absolute and Cross Calibration
  - Memory effect correction
  - Expose all engineering quality data with quality flags to identify engineering quality bands
- **TM-A format and LGAC data with minimal ephemeris include ESA data**
- **Automated Cloud Cover Assessment**
  - Recalculate ACCA for scenes in archive
  - Land ACCA score

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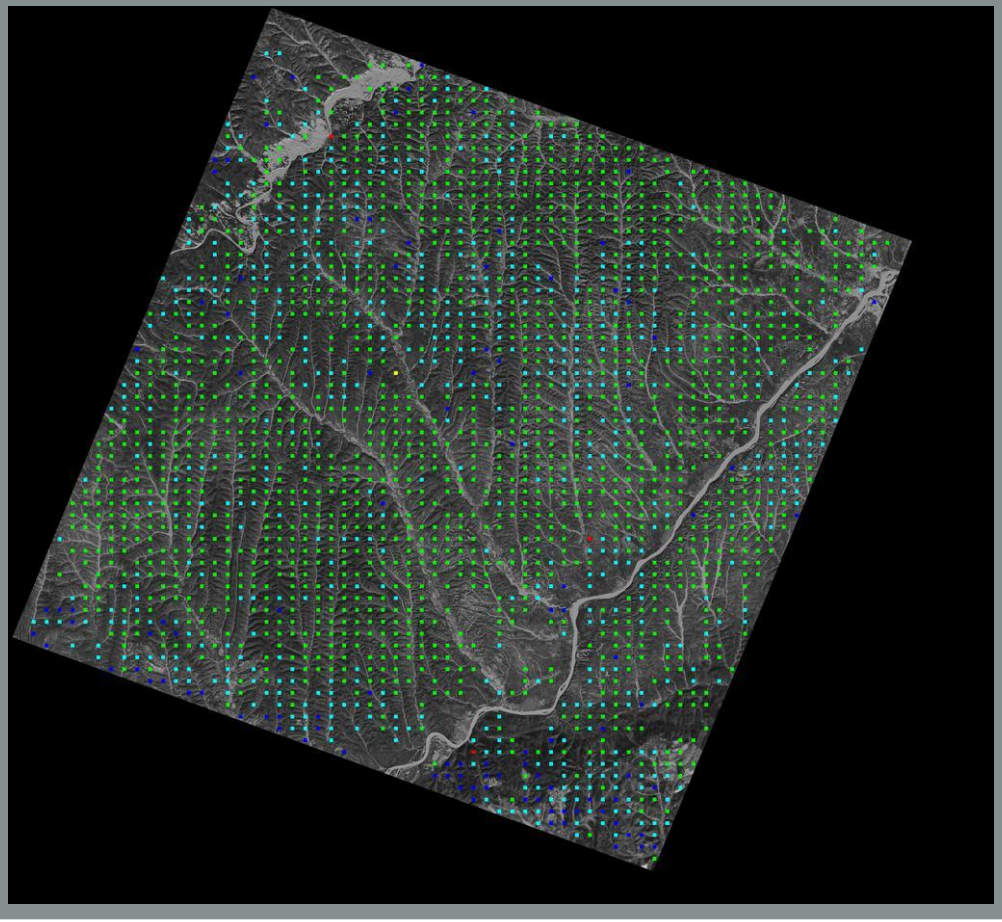
MSS & TM Geometric Accuracy

An example verification image delivered with L1T Product



Path/Row : 128/18 (WRS-1)

Legend :

Green - RMSE <= 0.5 pixel
Cyan - 0.5 < RMSE <= 1 pixel
Blue - 1 < RMSE <= 2 pixel
Yellow - 2 < RMSE <= 3 pixel
Red - RMSE > 3 pixel

GVERIFY_RMSE : 0.57 pixels

Precision fit and verification statistics reported in metadata

An L1T product does not guarantee a sub-pixel registration – check statistics in metadata

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Continued evolution of product

- **Replace GLS 2000 ETM+ reference database**
  - Inherent geometry of the OLI sensor should be better than the existing GLS 2000 reference database
  - Potential GLS 2015 database candidate for a new Landsat reference database
  - Create temporal Ground Control Point chip database extending from MSS through OLI
- **Replace the existing GLS DEM**
  - Currently the GLS DEM incorporated into GLS 2000 reference database prevents change from existing DEM prior to replacement of Landsat reference database
  - Globally consistent and distributable 30-meter global DEMs derived from ASTER and STRM data should be available for use by 2015

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Landsat Product Convergence

- **Product convergence with Landsat 8**
  - TOA ρ’ (reflectance without sun angle correction)
  - Quality/Cloud band
  - 16-bit data products (study)
    - LandsatLook GIS-ready visual product (complete)
    - Level 1 searchable and product metadata (complete)
- **Future plans**
  - Solar Elevation and Sensor Elevation Angle bands
  - New Landsat and DEM reference databases

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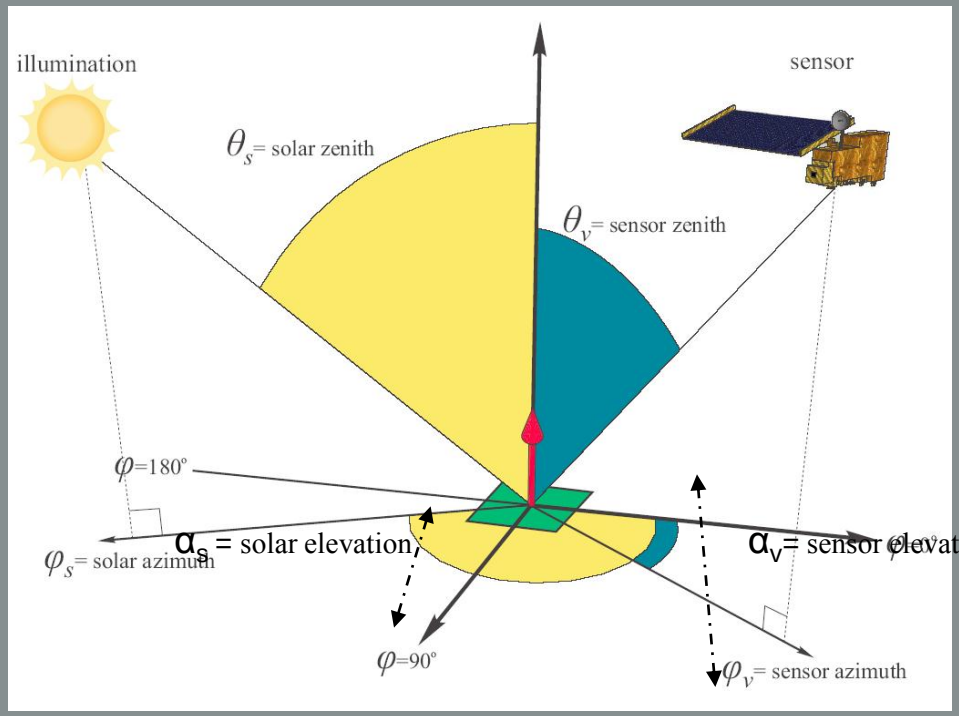
Solar and sensor elevation angles

- **Solar angle band (planned) – needed for per pixel TOA reflectance**
- **Sensor angle band (study) – needed for Bi-Directional Reflectance Distribution Function (BRDF) models**



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LDCM Quality Assessment (QA) Band

16-bit Level 1 QA Band

Bit	Description	Bit	Description
0	Designated Fill	8	Vegetation Confidence
1	Dropped Frame	9	
2	Terrain Occlusion	10	Snow/Ice Confidence
3	Artifact (Reserved)	11	
4	Water Confidence	12	Cirrus Confidence
5		13	
6	Cloud Shadow (reserved)	14	Cloud Confidence
7		15	

Confidence Levels
00 = none or unset
01 = 0-33% confidence
10 = 34-66% confidence
11 = 67-100% confidence

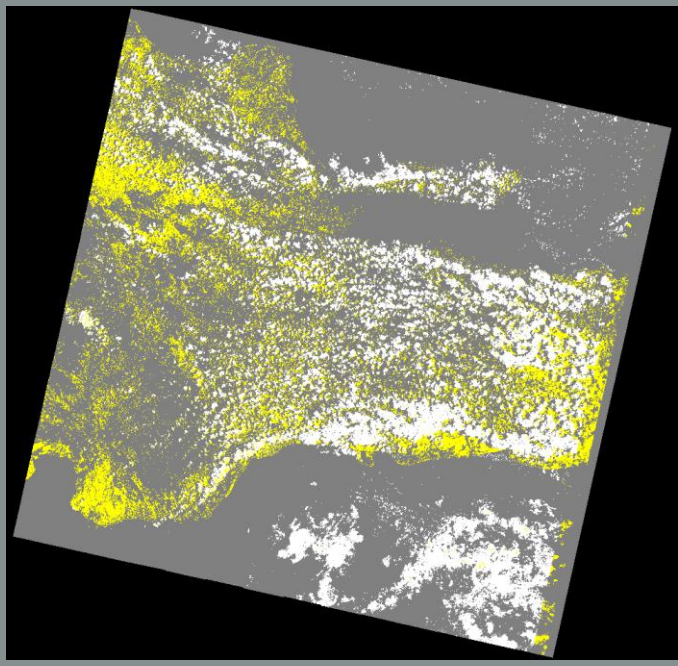
LDCM At-launch bits

Landsat 4, 5, 7
Designated Fill and Cloud bits only

LandsatLook QA band

Bit	Description
0	Designated Fill
1	Dropped Frame
2	Terrain Occlusion
3	Water**
4	Vegetation**
5	Snow/Ice**
6	Cirrus**
7	Cloud**

** Set for highest Confidence Level (11)



LandsatLook
Quality Assessment Band (8-bit)

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LDCM Standard Level-1T Products

- LDCM standard Level-1 data products will be consistent with heritage Landsat product specifications.
- OLI and TIRS data will be co-registered and distributed as a combined product.
- Metadata will include gain and offsets to convert OLI and TIRS data to at-sensor radiance, and to convert OLI data to at-sensor reflectance

Pixel size:	15m/30m/30m
Media type:	FTP
Product type:	Level-1T (precision, terrain correction)
Output format:	GeoTIFF
Map projection:	UTM (Polar Stereographic for Antarctica)
Datum:	WGS84
Orientation:	North up
Resampling:	Cubic convolution
Accuracy:	OLI 12m circular error, 90% confidence
	TIRS 41m circular error, 90% confidence

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Level-1T GeoTIFF Files

GeoTIFF Components
Level 1 image file (one for each band)
Level 1 metadata file
Quality band file

16-bit unsigned integer

.tar.gz file

Band Reference Number	Band	Band Center (nm)
B1	Coastal Aerosol	433
B2	Blue	482
B3	Green	562
B4	Red	655
B5	NIR	865
B6	SWIR 1	1610
B7	SWIR 2	2200
B8	Panchromatic	590
B9	Cirrus	1375
B10	TIRS 1	10800
B11	TIRS 2	12000

Band Reference Table

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LDCM Version of LandsatLook

- Full spatial resolution image and retains the map projection of the source data (normally polar stereographic for Antarctic scenes and UTM elsewhere).
- Derived from Level-1T product
- 16-bit TOA reflectance data rescaled to 8-bits per band
- 3-band image consistent with legacy Landsat browse
  - band 6 (1610 nm), band 5 (865 nm) and band 4 (655 nm) for the red, green and blue components of the browse
- The three bands are then combined to generate a 24-bit color image which is JPEG compressed with a quality of 75%.
- Intended to satisfy broader use without the need for sophisticated processing
- The TIRS browse is generated by extracting the 10.8 um band from the level-1 product and scaling to an eight bit grayscale image (the exact scaling parameters are TBD).

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Higher Level Science Products

- Research and development outside the formal ground system infrastructure
- Climate Data Records
  - ✓ Calibrated radiances
  - ✓ Surface reflectance (NASA GSFC, UMD)
  - Land surface temperature (JPL, RIT)
- Essential Climate Variables
  - Land Cover (annual continuous fields, 5-year classifications)
  - Surface water extent
  - Leaf area index (NASA ARC)
  - Burned area
  - Snow Cover Extent

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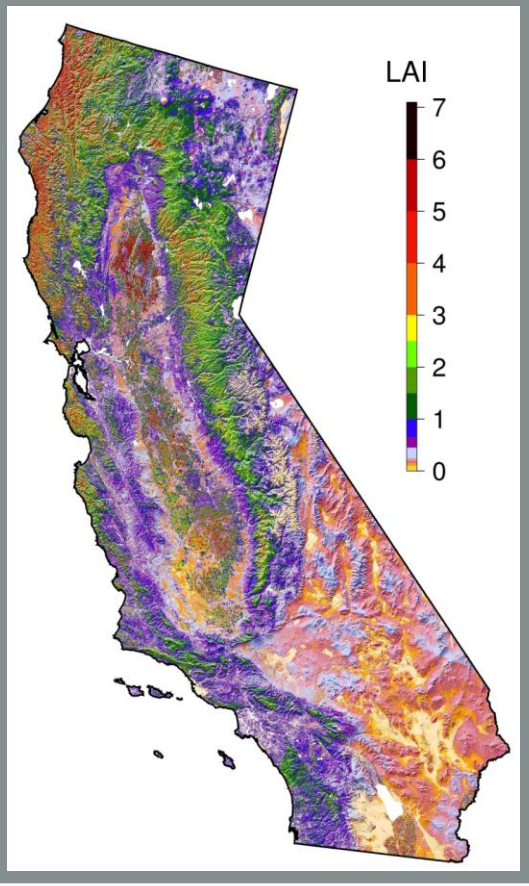
From Data to Information

L1T At-sensor Radiance

Surface Reflectance

Leaf Area Index



Courtesy Rama Nemani, NASA Ames Research Center

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Summary

- **Continue improvement of geometry and radiometry of Landsat products**
- **Create a consistent Landsat product line**
  - Continue to evolve the Landsat Level 1 Product
- **The development of higher level information products are under research and development (climate data records, essential climate variables)**
  - Landsat Science Team participation in the formulation, development, implementation, and evaluation is key to successfully accomplishing these goals

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Backup Slides

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TOA Reflectance

- **Ratio of the radiant power reflected from Earth to the radiant power incident on it**

$$\rho = \frac{\pi \, x \, L \; x \, ES_{dist}^{\;2}}{ESUN \; x \; \cos\theta_{sz}}$$

- **Earth/atmosphere system**
  - No atmospheric correction
  - Assumption of Lambertian reflector
  - No terrain slope/aspect correction

  - Sun elevation angle (90^{o}-θ_{sz}) accounts for spatial and temporal differences in solar irradiance between data acquisitions due to seasonal change in sun declination angle (tilt of the Earth combined with Earth's rotation around the sun)
  - Earth-Sun distance (ES_{dist}), accounts for seasonal variability in sun irradiance due to elliptical Earth's orbit around the sun
    - ES_{dist} varies from 0.9833 to 1.0167 AU (~±3.3% effect)
  - ESUN is exoatmospheric solar spectral irradiance weighted by the sensor's spectral response
    - It can vary up to ~3.4% (or more), depending on the solar spectrum used
    - Helps comparability of data acquired by different sensors

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TOA ρ' Product

- **ρ' – reflectance without sun elevation correction**
  - Can provide coefficients in metadata to calculate
    - L $L = M_L Q_{cal} + A_L$
    - ρ' $\rho' = M_\rho Q_{cal} + A_\rho$
    - ρ_{SC} $\rho_{SC} = \rho' / \cos(\theta_{SZ})$
    - ρ_{pp} $\rho_{pp} = \rho' / \cos(\theta_{pp})$
  - To generate scene-center reflectance, ρ_{sc}, users and vendors will need to extract the scene center sun angle (θ_{SZ}) from the metadata and apply the correction.
  - To generate per-pixel reflectance, ρ_{PP}, users and vendors will need to calculate per pixel sun angles (θ_{pp}) for scene and apply the correction
  - Can easily backout to radiance

- **Q_{cal} - quantized and calibrated DN values**
- **M and A are the band-specific multiplicative and additive scaling factors stored in metadata**
- **$\theta_{SZ} = 90^o - \theta_{SE}$, θ_{SE} is solar elevation angle**

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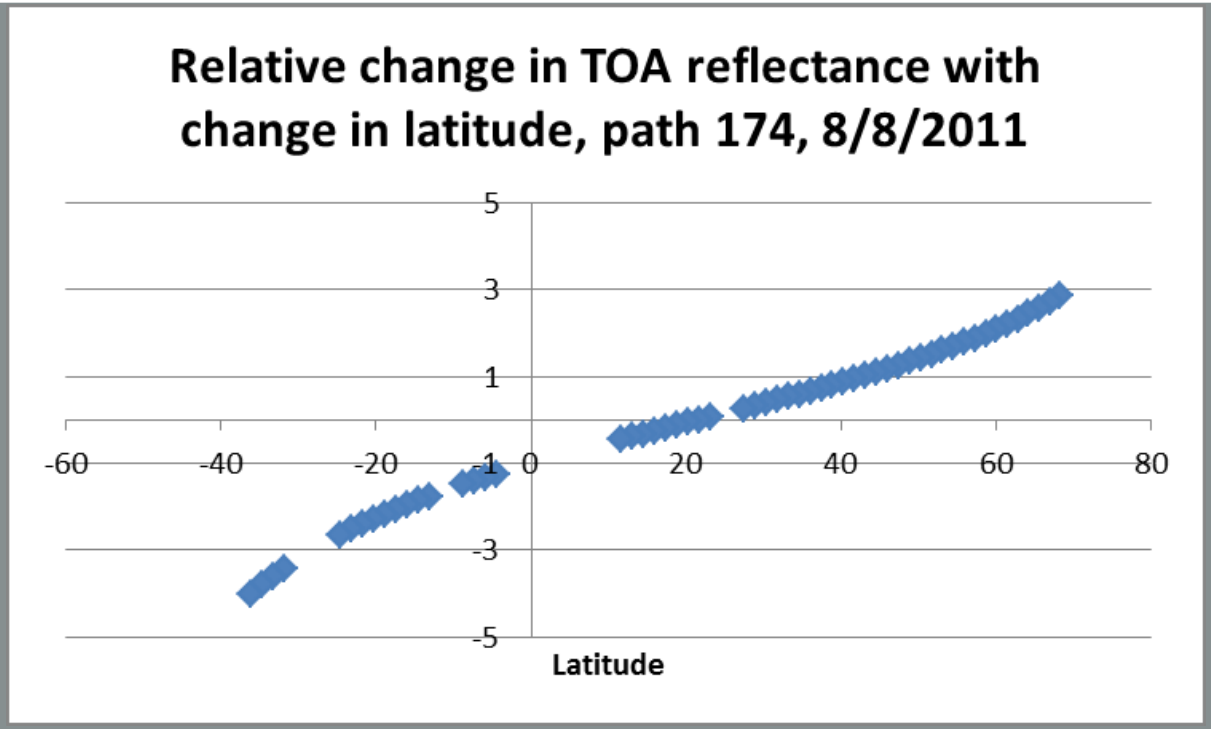
TOA reflectance (ρ_{sc}) vs. latitude



- For a given date, relative change in reflectance from scene center to scene center along WRS path vs. latitude
- Scene-center correction for example of August 8 (not the worst case) results
  - in ~3.5% difference in the along-track scene overlap pixels at 75 degrees latitude (Northern Greenland)
  - in ~1% difference in the along-track scene in overlap pixels at 42 degrees latitude (Chicago, Rome, Beijing)

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