Comparing IKONOS and Landsat 7 Images

Insights from Computer Simulations

Slawomir Blonski

Lockheed Martin Space Operations – Stennis Programs

Remote Sensing Directorate

Stennis Space Center, Mississippi

228-688-1944

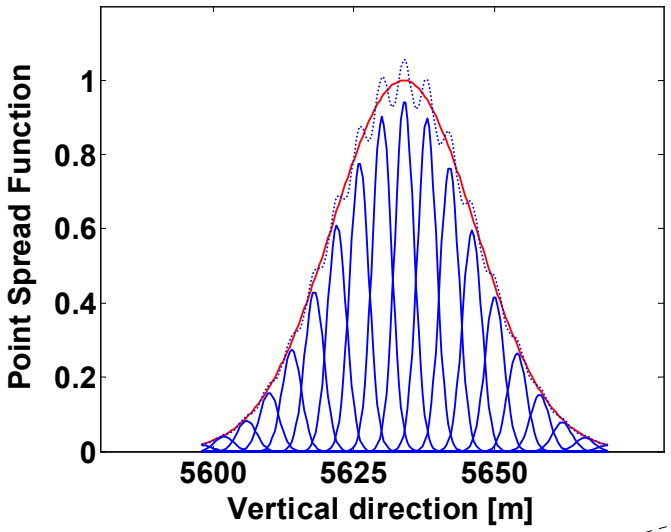
sblonski@ssc.nasa.gov

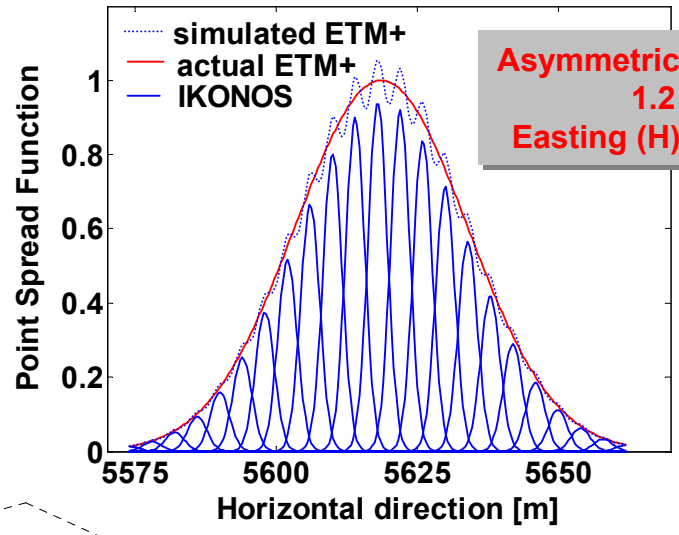
Landsat 7 Simulations

- Current work is a continuation of the simulations presented at the previous workshop
- 20 IKONOS images compared with 10 Landsat 7 ETM+ VNIR images acquired on the same days
- Comparisons are based on simulations of the Landsat 7 images from the IKONOS data
- IKONOS and Landsat 7 images used in the simulations are on similar processing level:
  - radiometric correction
  - georeferenced with cubic-convolution resampling
  - UTM projection with WGS-84 datum

IKONOS Image ID	WRS-2 Path / Row	Date
po_64505	41 / 37	2000-12-27
po_45306	16 / 43	2000-09-07
po_37741	28 / 35	2000-05-22
po_45302	46 / 29	2000-08-08
po_45281		
po_45301		
po_41229	29 / 29	2000-06-30
po_53177		
po_58771		
po_70164		
po_53954	29 / 30	2000-06-30
po_59751		
po_43663	173 / 35	2000-03-27
po_43664		
po_43672		
po_34524		
po_34517		
po_52843	173 / 35	2000-10-05
po_42026	129 / 48	2000-11-02
po_44653	175 / 71	2000-04-10

Simulation Algorithm: PSF Synthesis

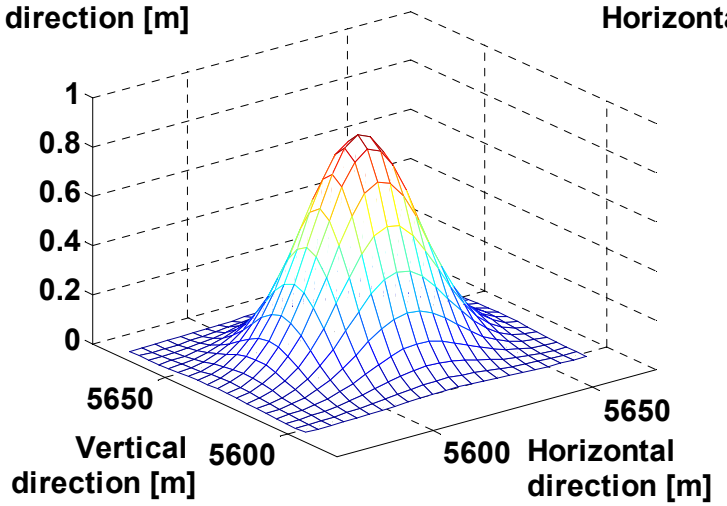




Asymmetric Landsat 7 PSF
1.2 : 1.0
Easting (H) : Northing (V)

For each spectral band, a Landsat 7 image (I') is simulated by linear combination of IKONOS image (I) pixels:

$$I'_{kl} = \frac{\sum_i \sum_j c_{ijkl} I_{ij}}{\sum_i \sum_j c_{ijkl}}$$



Coefficients c_{ijkl} are found independently for each Landsat 7 pixel by solving (in the least squares sense) for a given set of points (x, y) the following equation which expresses an effective point spread function (PSF') of the Landsat 7 image as a linear combination of the IKONOS image PSF's:

$$PSF'(x - x_l, y - y_k) = \sum_i \sum_j c_{ijkl} PSF(x - x_j, y - y_i)$$

California Images

Images acquired on December 27, 2000

<u>Landsat 7</u>

- path 41 row 37
- 18:19 UTC

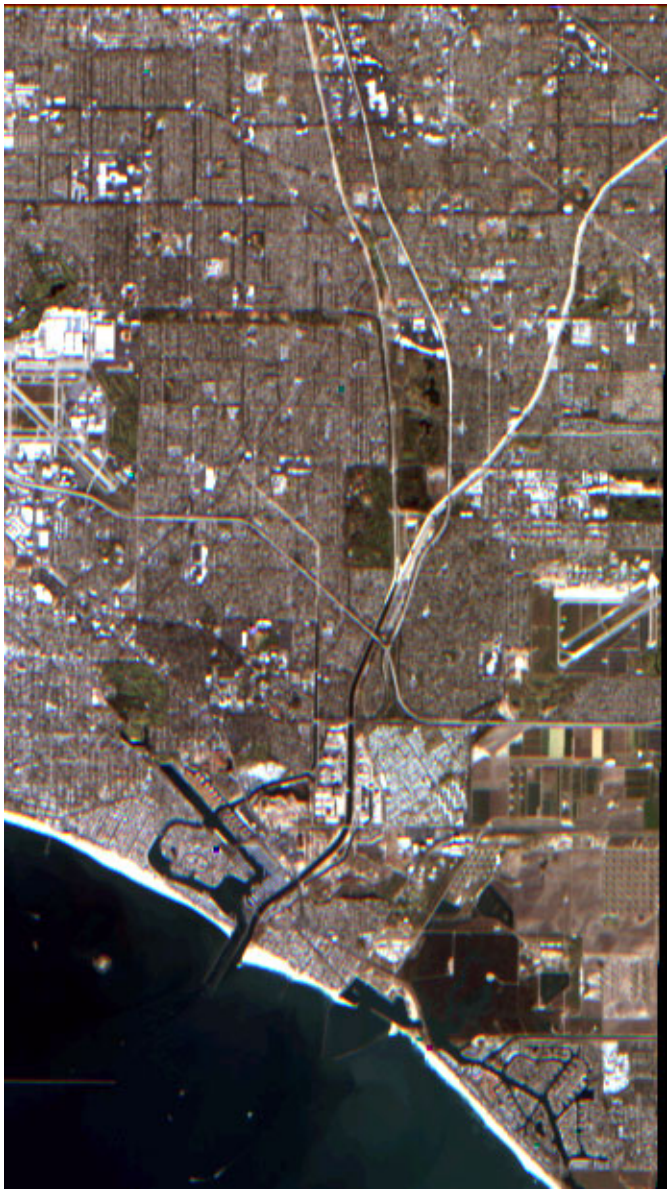
<u>IKONOS</u>

- po_64505
- 18:21 UTC

Almost the same acquisition time

Remarkable visual agreement between the RGB images

Actual Landsat 7 ETM+



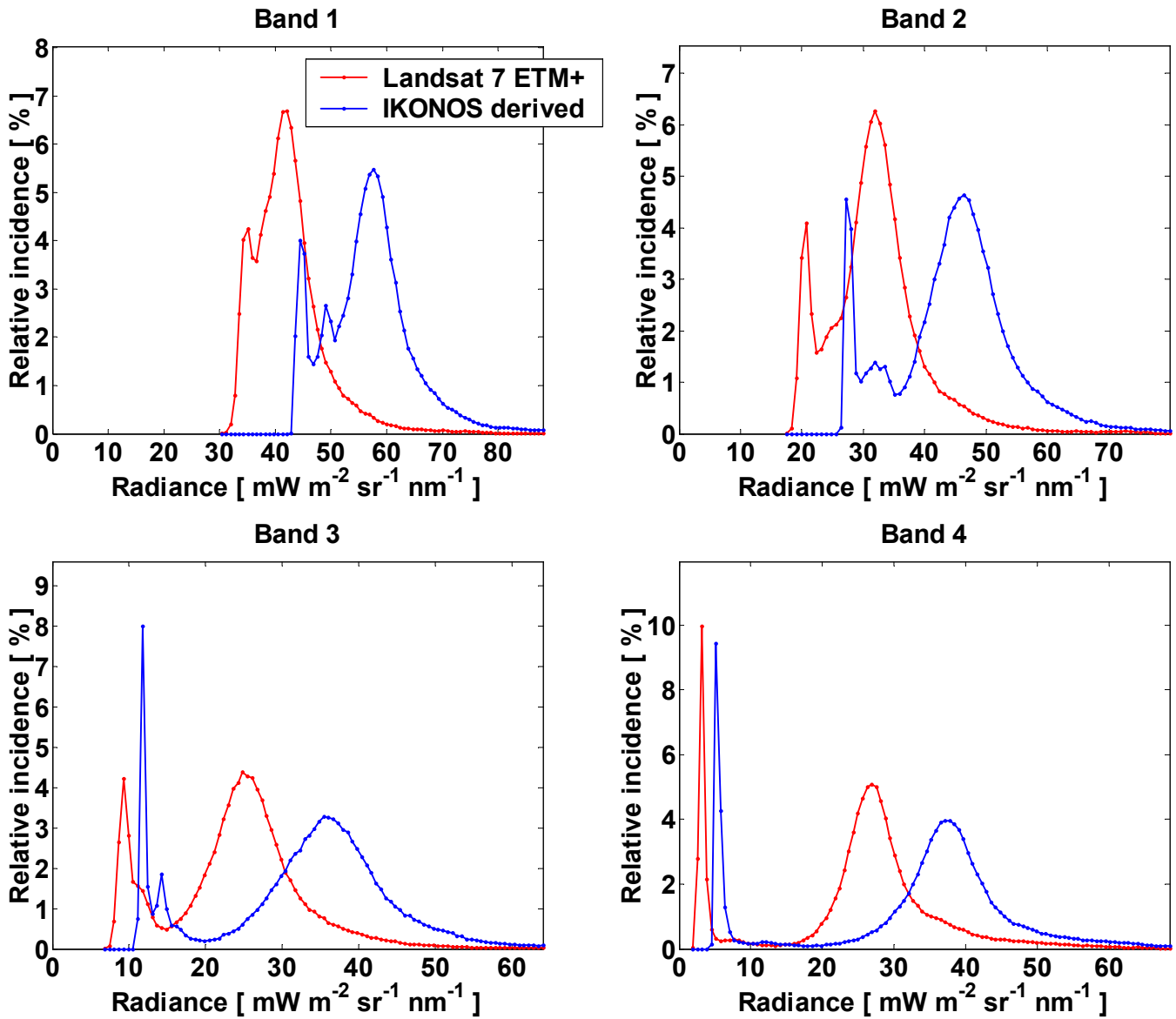
Landsat 7 ETM+ simulated from IKONOS

California Histograms

Radiance recorded in the IKONOS image is higher by as much as 50% than radiance measured by Landsat 7 ETM+

These results are typical for all the IKONOS – Landsat 7 simulations:

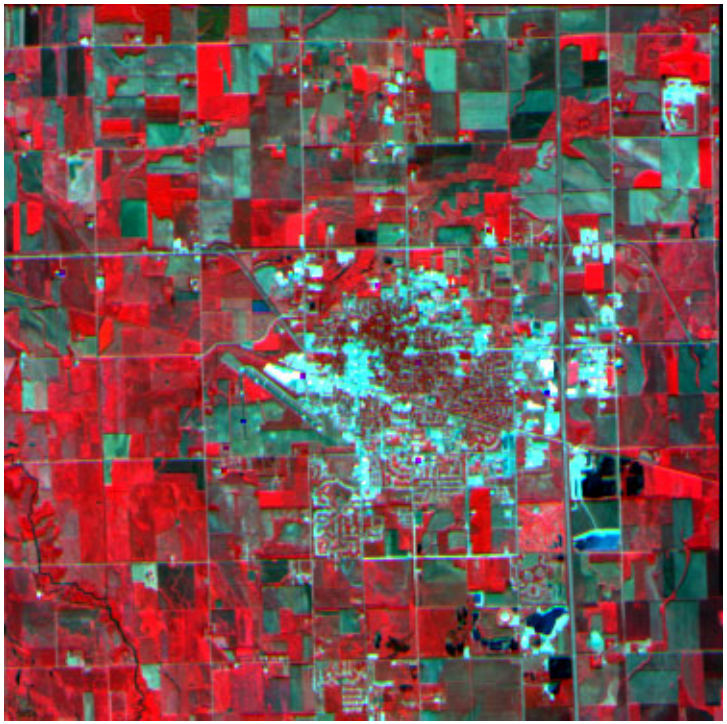
- Good visual agreement
- Substantial radiometric differences

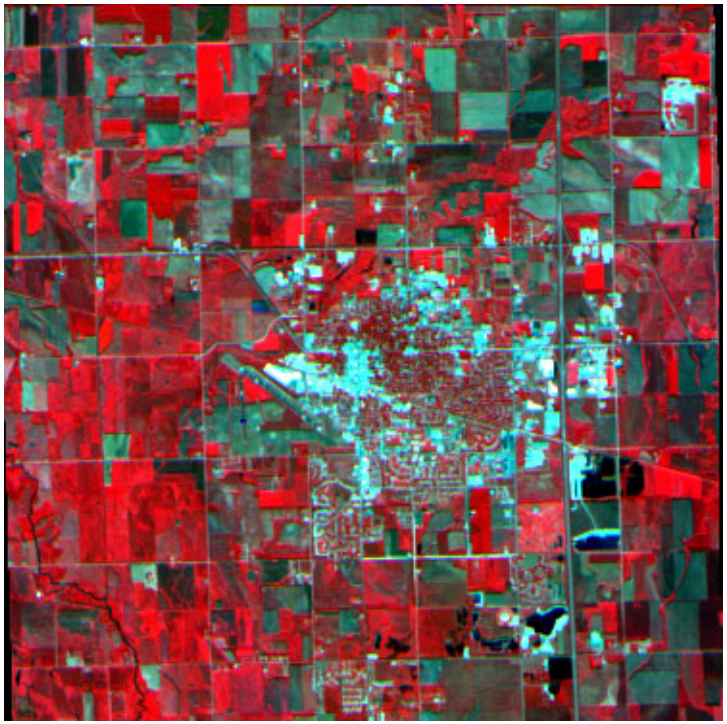


Brookings Images

Images acquired on June 30, 2000

- **Landsat 7 p29 r29 17:03 UTC Elev. ~90°**
- **IKONOS po_41229 17:12 UTC po_58771 17:13 UTC**
  Elev. 73° Azim. 0° Elev. 85° Azim. 302°





Landsat 7 ETM+ images simulated from the IKONOS images using the PSF synthesis

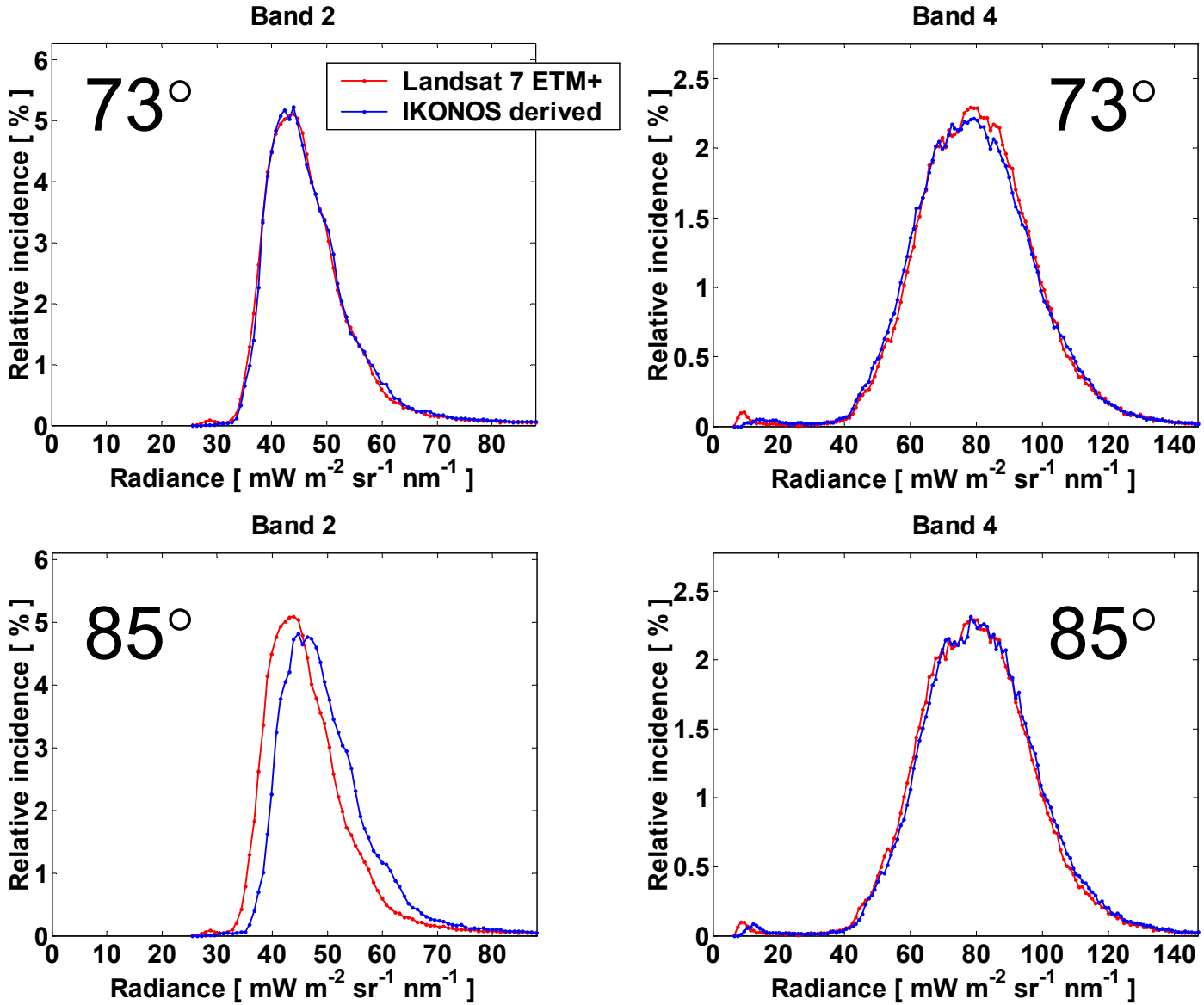
Brookings Histograms

This is the best radiometric agreement achieved in all the Landsat 7 simulations based on IKONOS imagery

IKONOS image acquired at the higher elevation angle clearly differs from the Landsat 7 image

Time not a factor: both IKONOS images acquired 9 to 10 minutes after the Landsat 7 image

Results for bands 1 and 3 similar to those for band 2



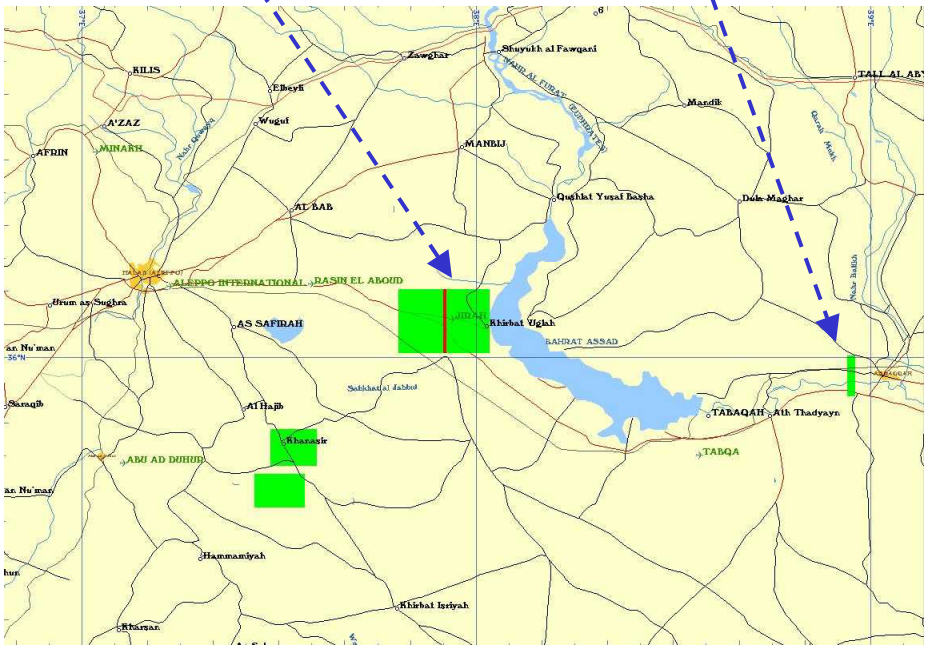
Syria Images

Two IKONOS images acquired over Syria on March 27, 2000, were selected for comparison with a Landsat 7 ETM+ image:

- **Landsat 7**
  p173 r35 7:56 UTC

- **IKONOS**
  ***po_43663* 7:58 UTC** ***po_43672* 7:59 UTC**

Similar terrain features in both IKONOS images: fields, desert, water bodies



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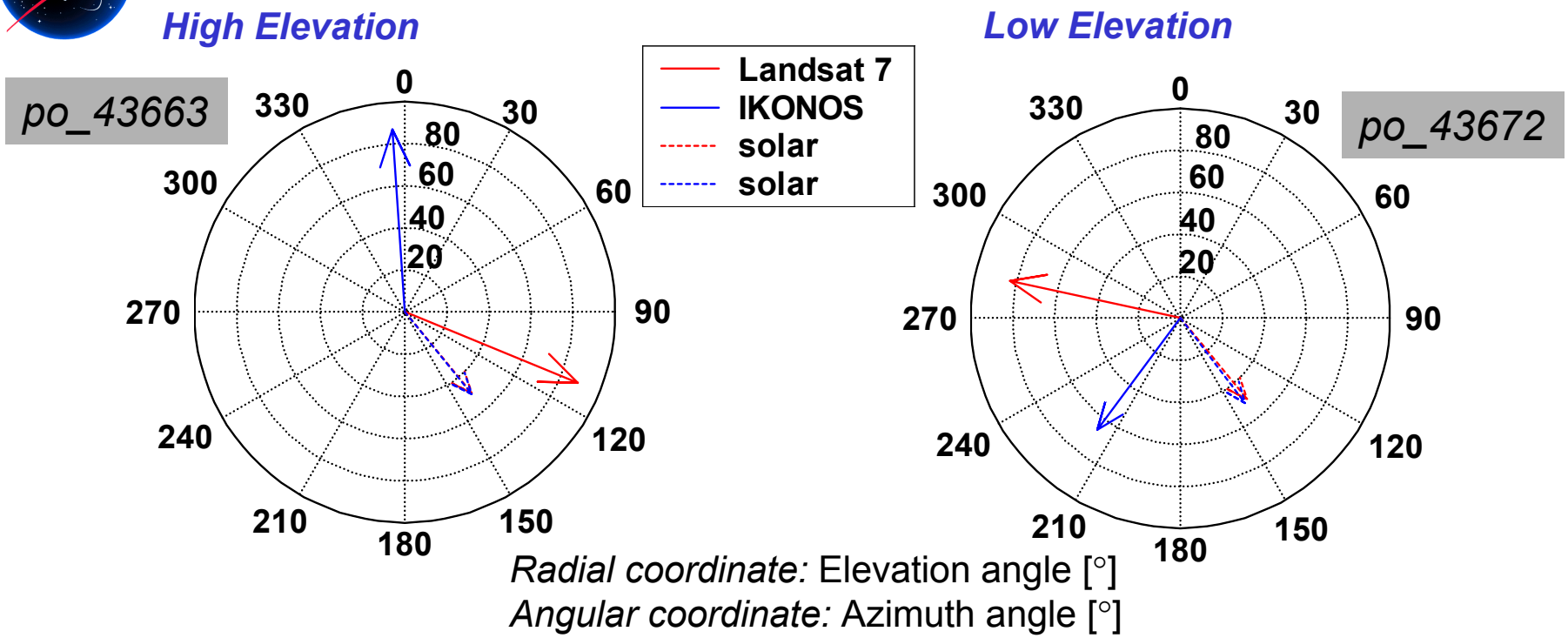
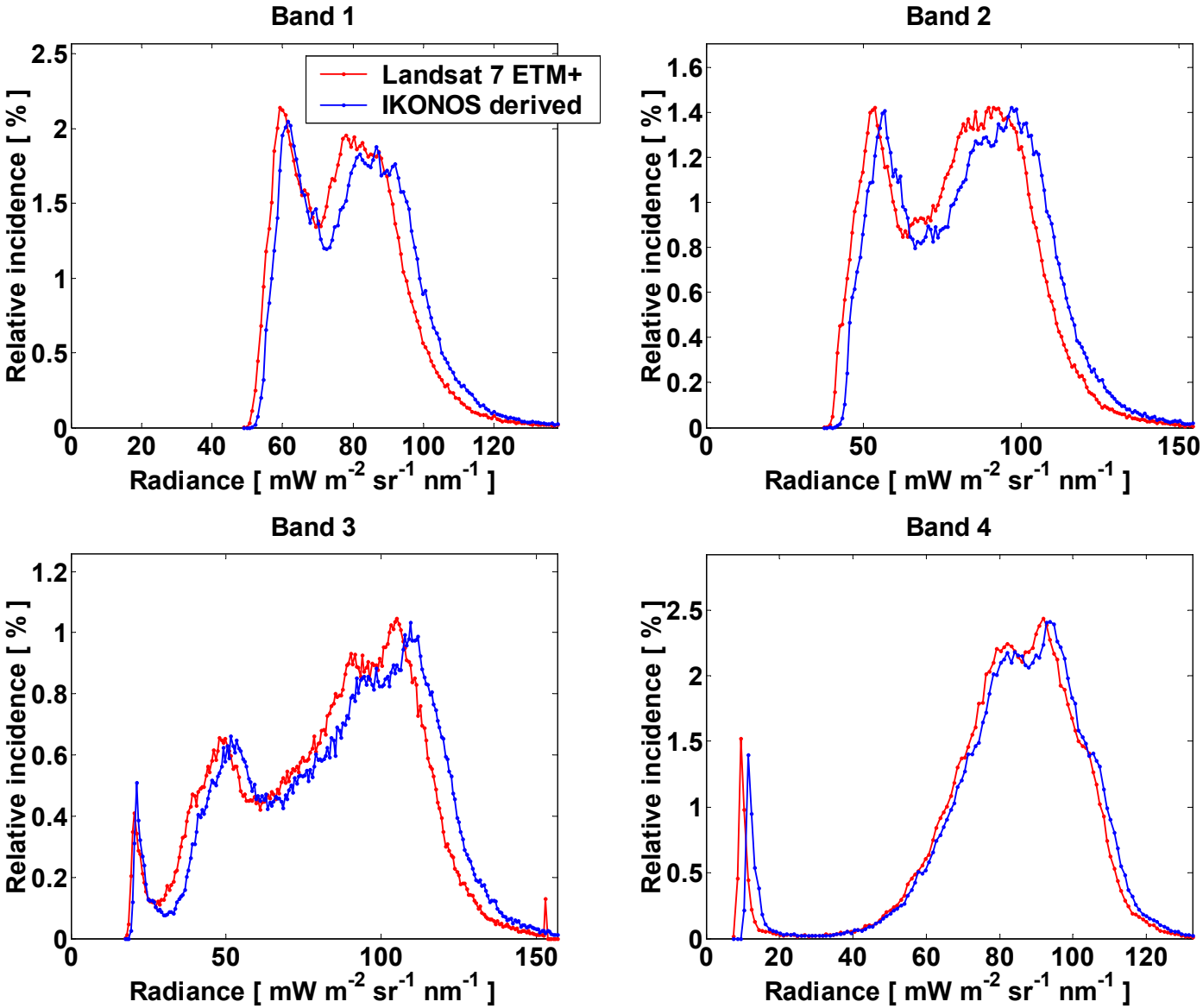
Syria Collection Geometry



- IKONOS collection geometry is significantly different for the two Syria images (both in elevation and azimuth)
- Landsat 7 geometry is different as well because ground track passed in between the two image sites
- Solar geometry is almost the same for both image pairs, thus the sun-satellite bi-directional angles are different

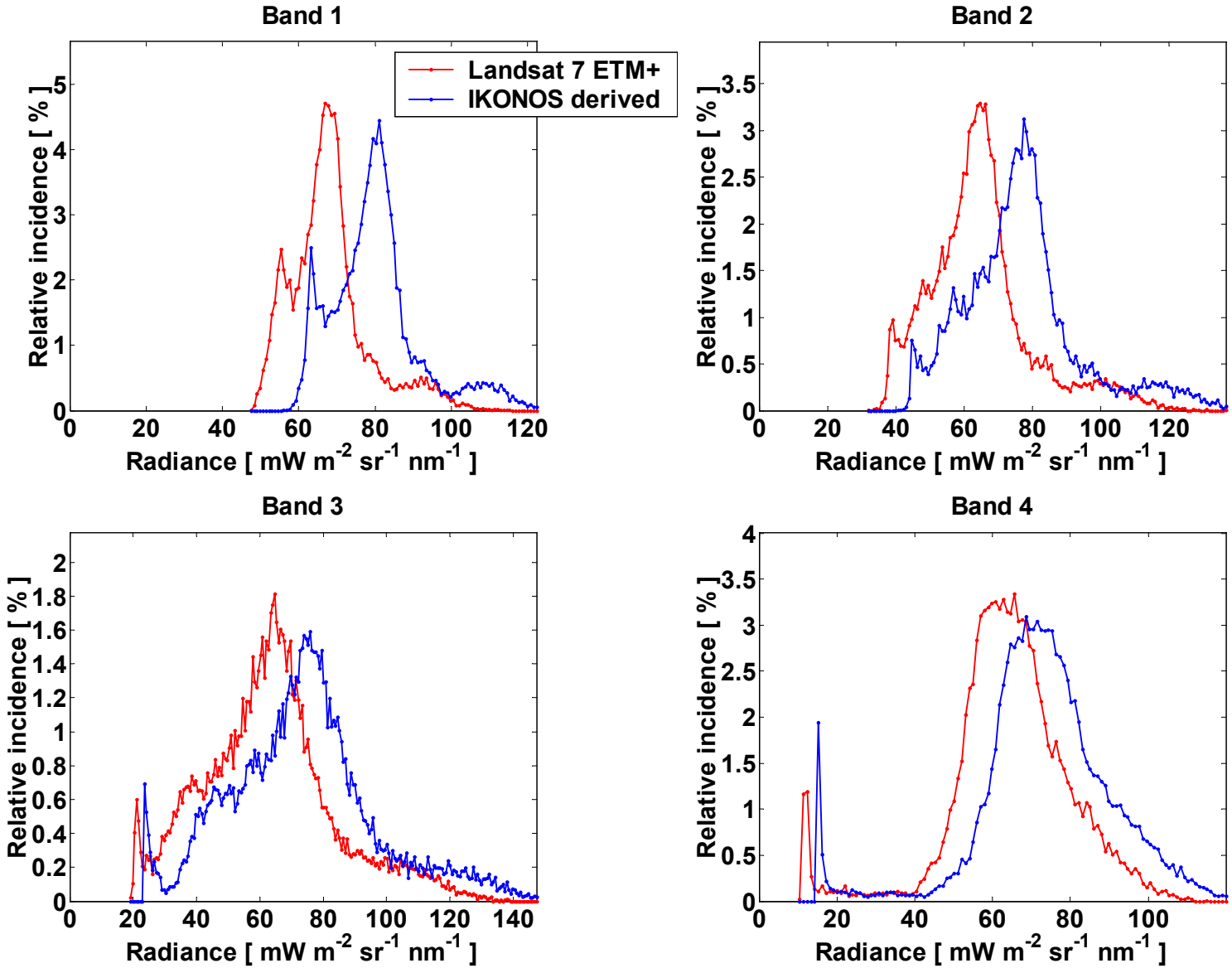
Syria High-Elevation Histograms

The differences between radiance recorded in the IKONOS image and radiance measured by Landsat 7 ETM+ are relatively small



Syria Low-Elevation Histograms

The differences are more prominent for the images acquired from the low elevation than for the high-elevation images

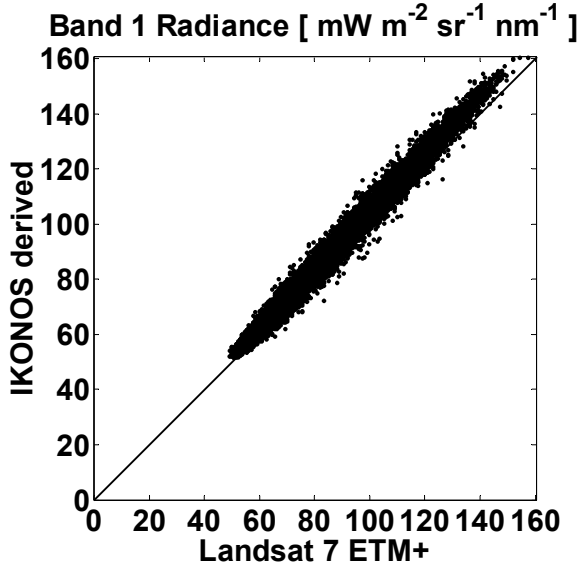


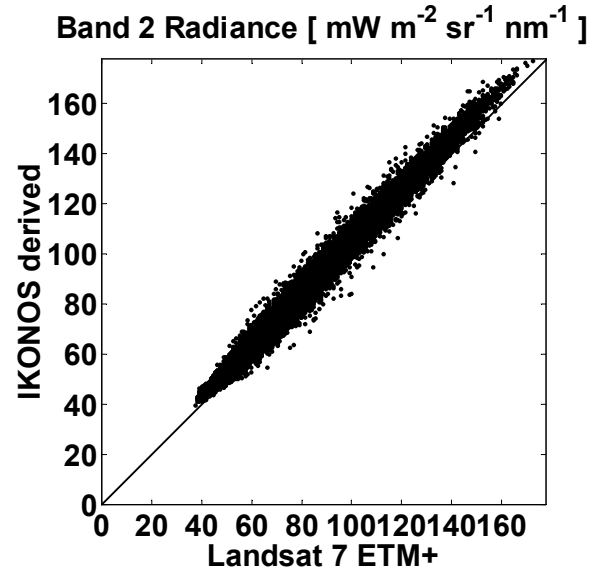
Syria High-Elevation Scatter Plots

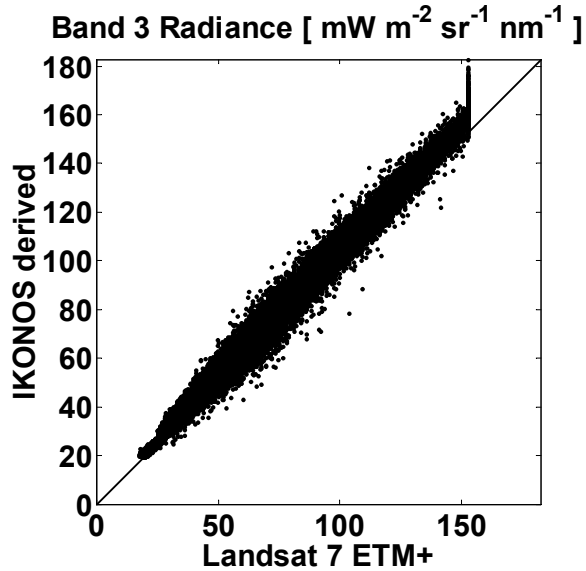
Scatter plots confirm good co-registration between actual and simulated pixels

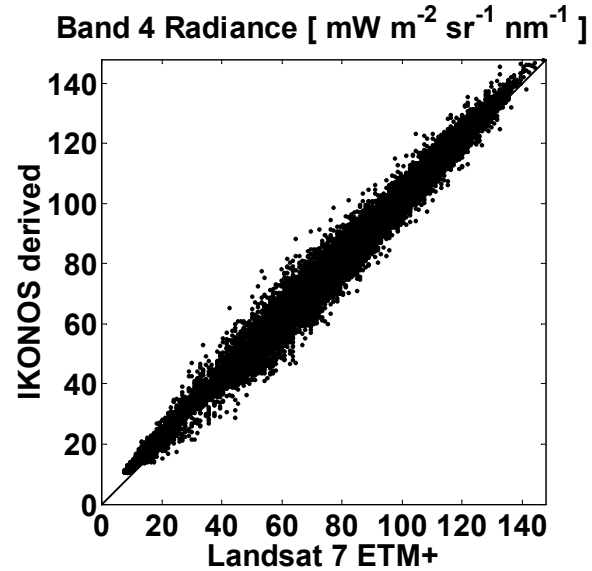
Radiometric differences agree with those shown on histograms:

IKONOS-measured radiance values are larger by 5% than the Landsat 7 ETM+ measurements for bands 1, 2, and 3









Syria Low-Elevation Scatter Plots

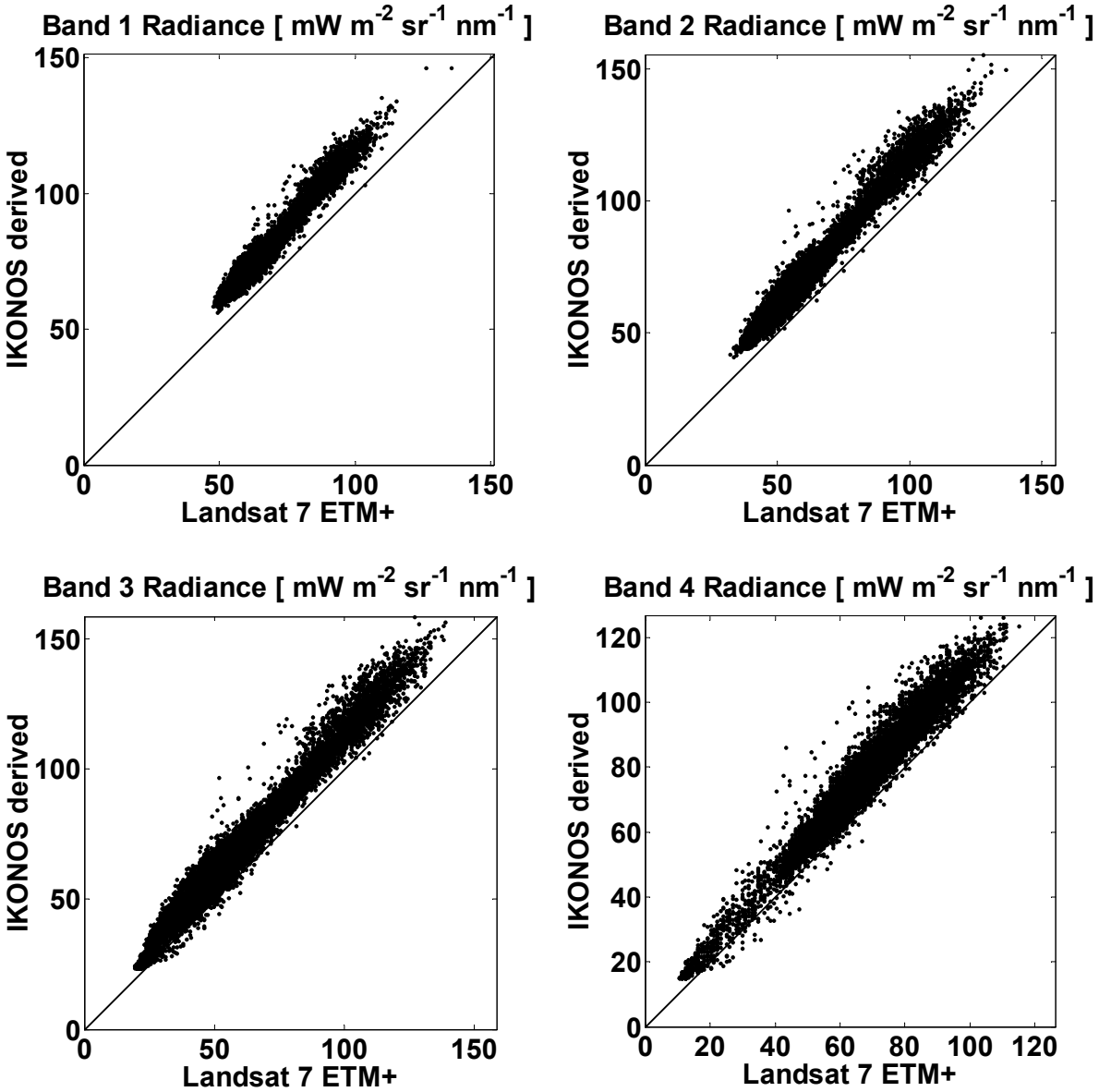
Co-registration between actual and simulated pixels is still satisfactory

Radiometric differences also agree with those shown on histograms:

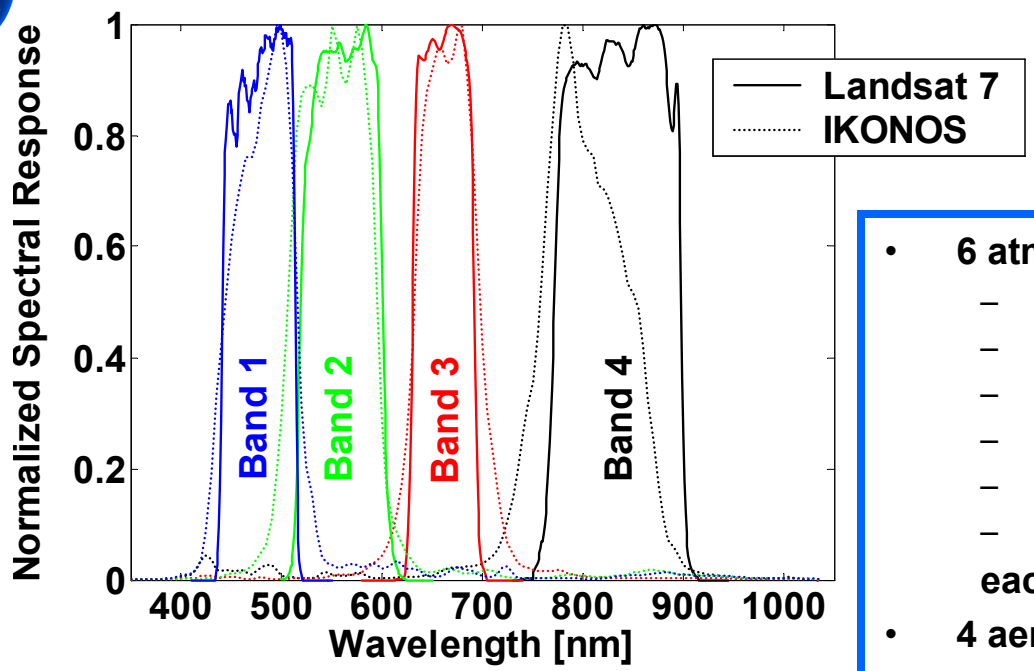
IKONOS-measured radiance values are larger by 18% than the Landsat 7 ETM+ measurements for bands 1, 2, and 3

There appears to be an additive term (atmospheric path radiance) besides the multiplicative term (atmospheric transmission):

Atmospheric correction is needed for IKONOS comparisons with Landsat 7



Spectral Response Comparison



- Undertaken to evaluate effects of differences between spectral responses of IKONOS and Landsat 7 ETM+
- ~30,000 MODTRAN4 calculations for each sensor
- 1287 surface reflectance spectra from ASTER library (JHU, JPL, and USGS) and USGS Spectroscopy Lab
- Mainly minerals, but also vegetation, soils, and man-made materials

MODTRAN modeling

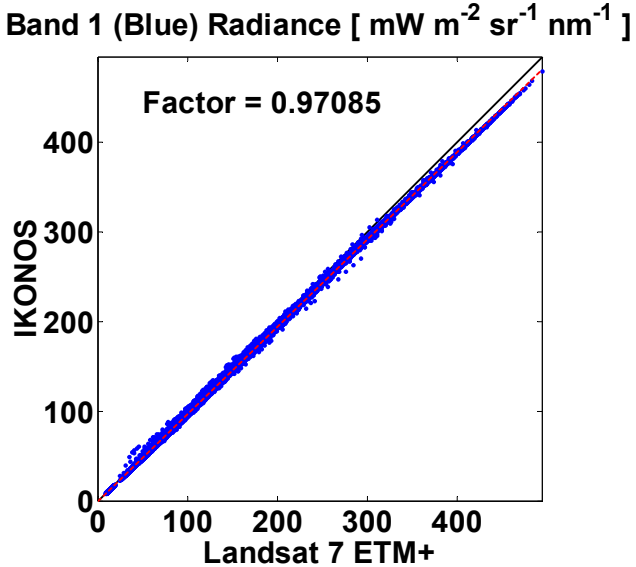
- 6 atmospheric models
  - tropical at 30°N on June 22
  - tropical at 30°N on Dec. 22
  - mid-latitude summer at 45°N on June 22
  - mid-latitude winter at 45°N on Dec. 22
  - sub-arctic summer at 60°N on June 22
  - sub-arctic winter at 60°N on Dec. 22

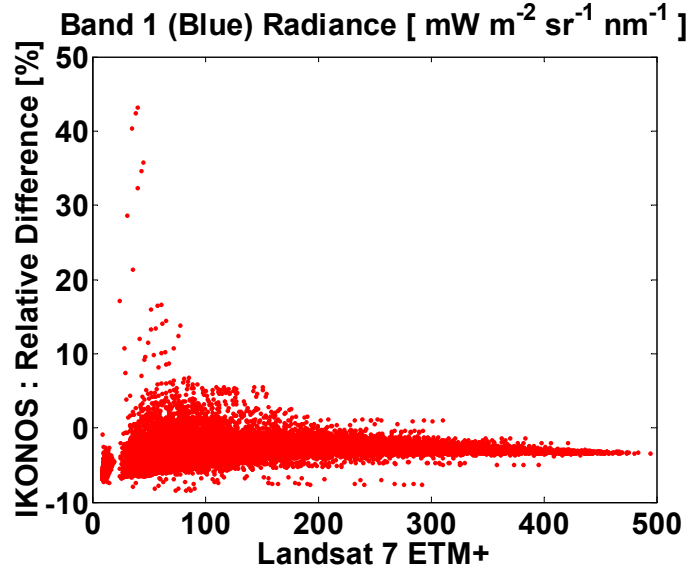
  each combined with
- 4 aerosol models
  - rural, VIS = 23 km
  - rural, VIS = 5 km
  - urban, VIS = 5 km
  - tropospheric, VIS = 50 km
- nadir geometry from space for both sensors
  - 100 km altitude
  - ground at sea level
  - longitude 0°
  - 10:00 UTC

MODTRAN Results: Bands 1 & 2

Band 1:

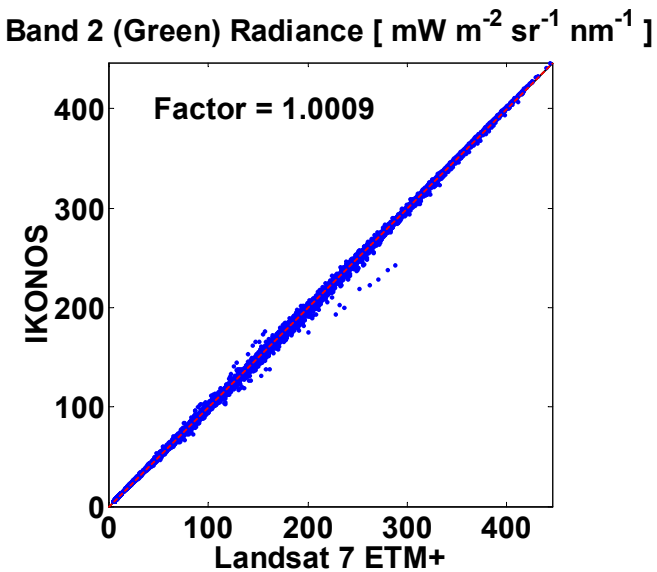
Good agreement between IKONOS and Landsat 7 ETM+ radiances (differences of few percent only)

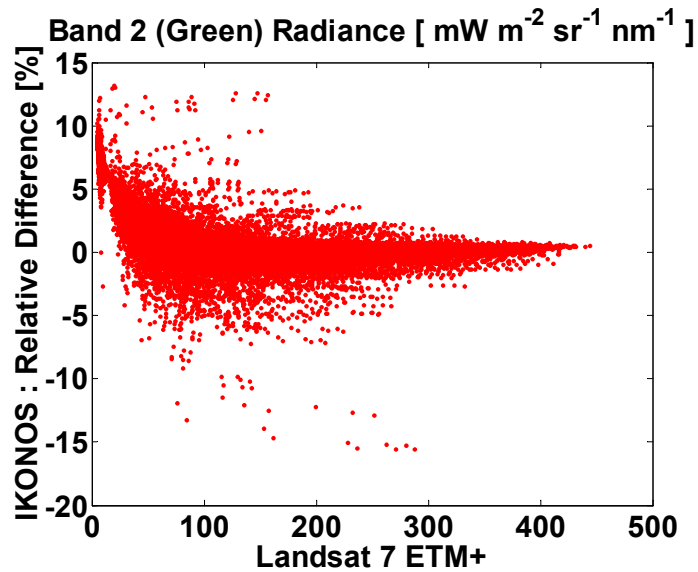




Band 2:

Good agreement as well (differences of up to 10% for dark objects)

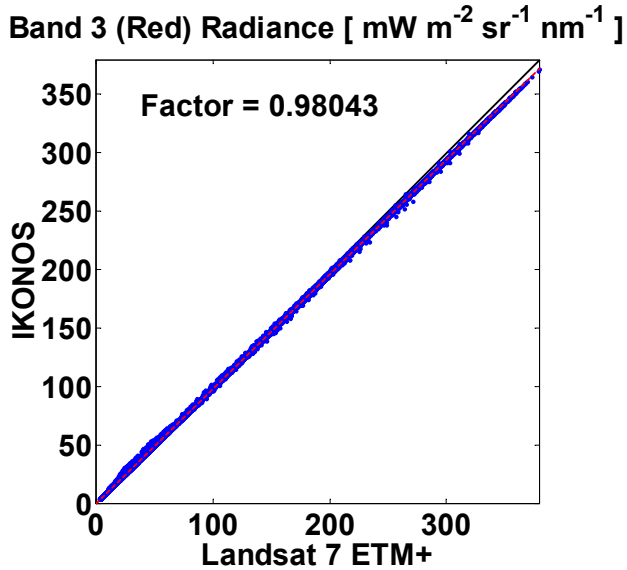


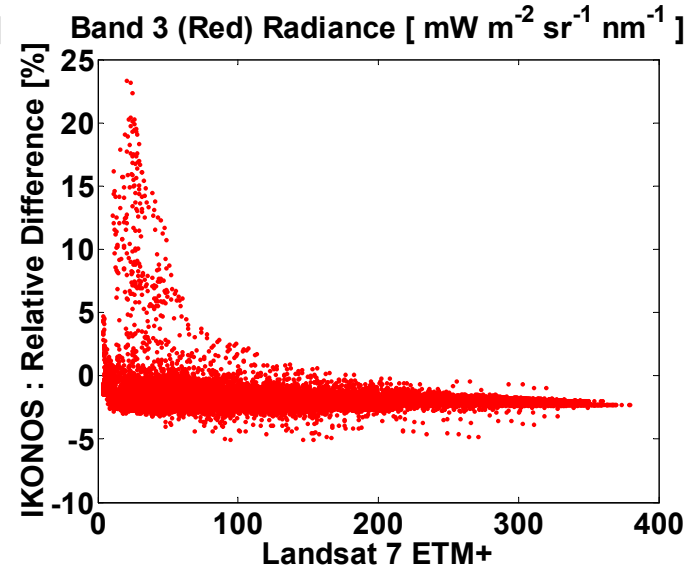


MODTRAN Results: Bands 3 & 4

Band 3:

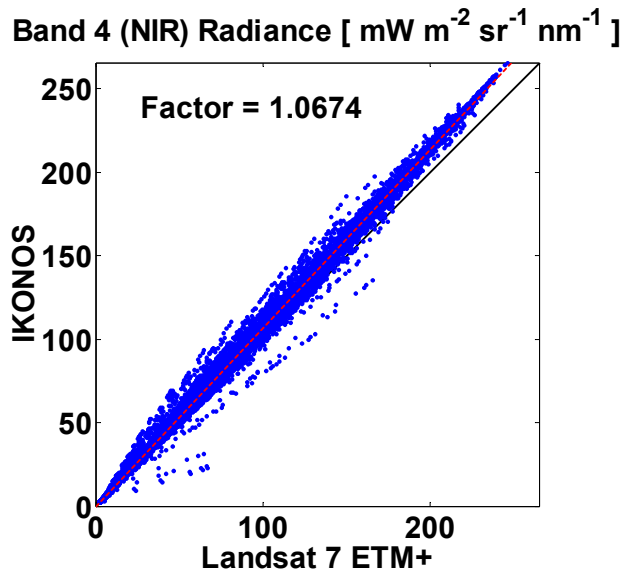
Very good agreement between IKONOS and Landsat 7 ETM+ radiances (differences of a couple of percent only, although more for some objects)

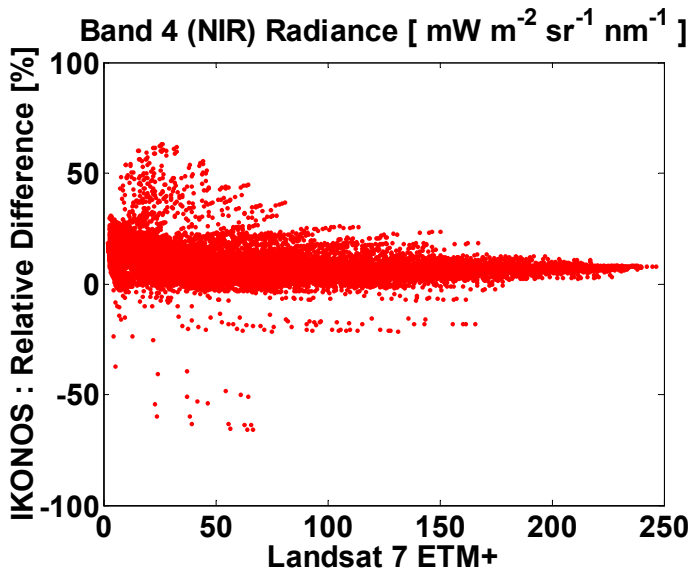




Band 4:

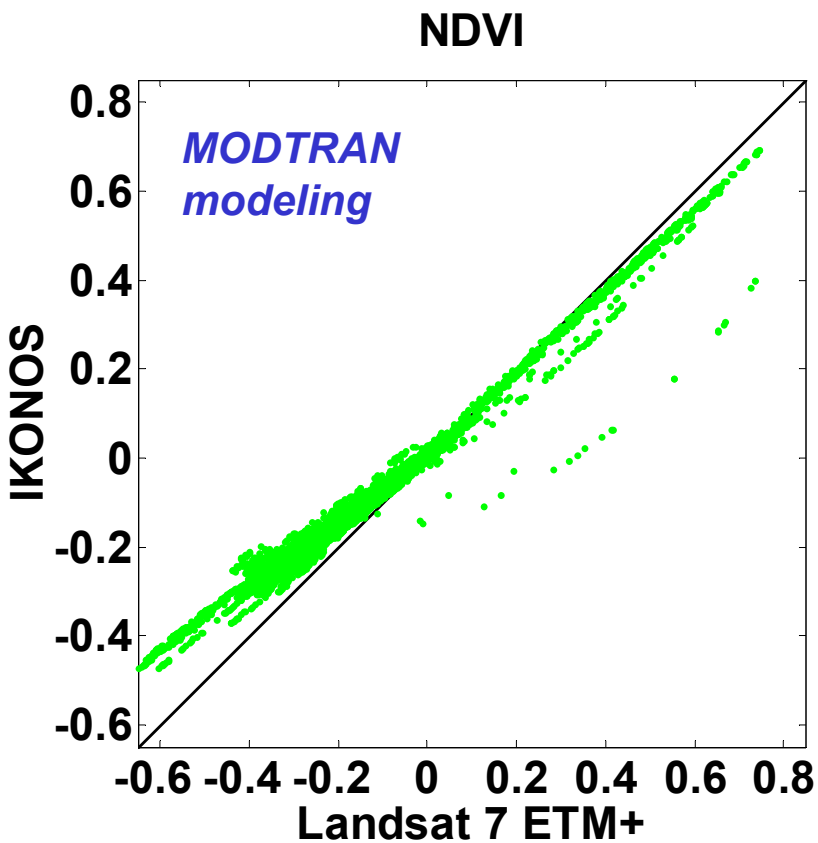
Some disagreement visible (differences of up to 20% for most objects)

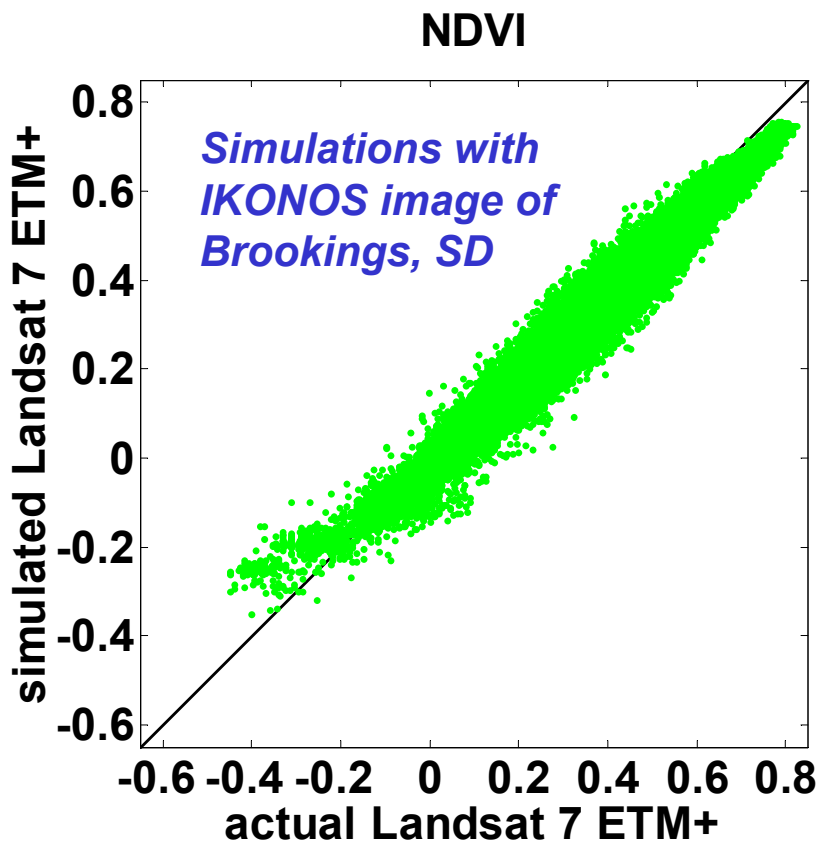




NDVI Comparison

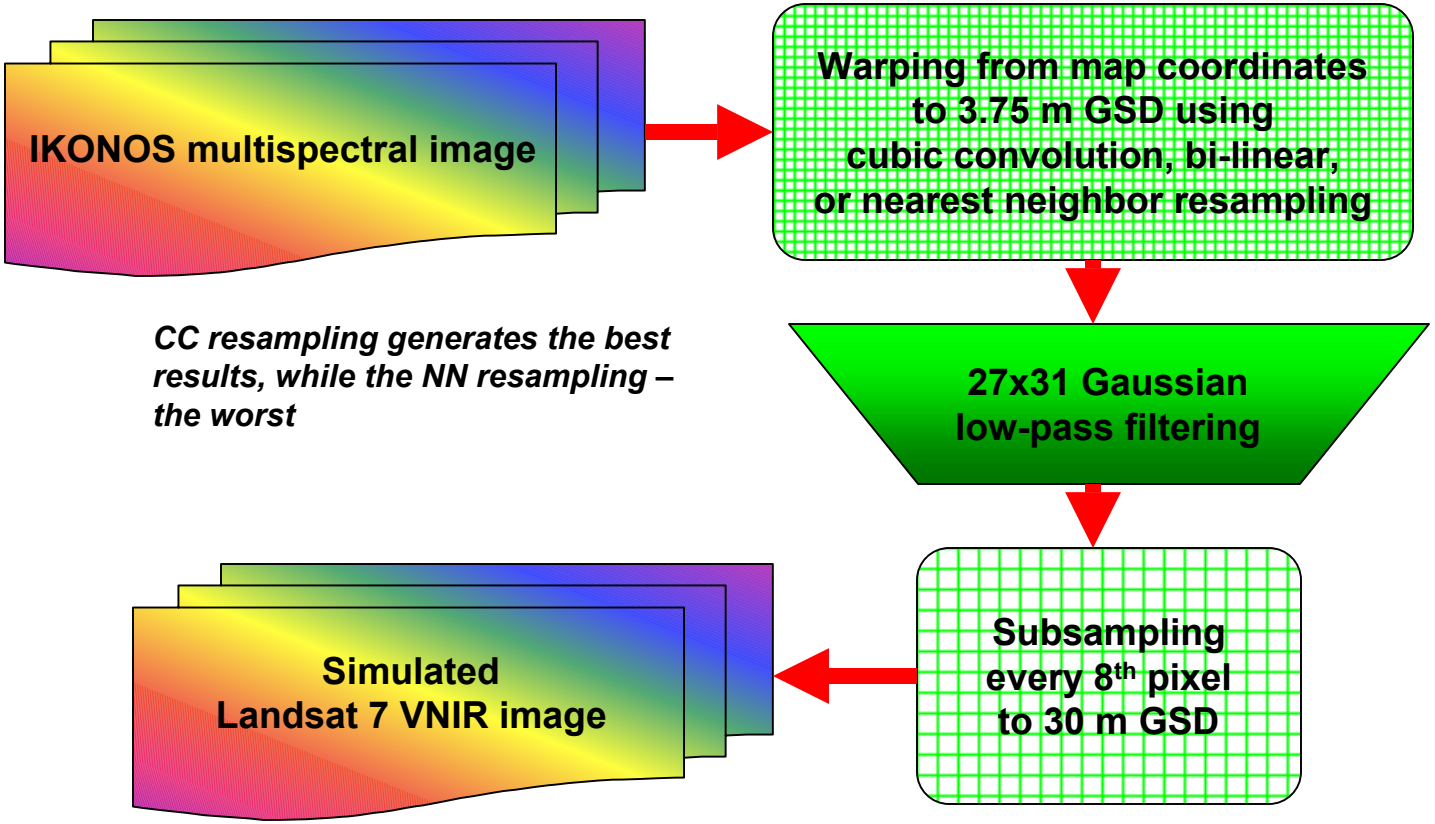
Although reflecting surfaces used in the MODTRAN modeling differ from surfaces occurring in the Brookings scene, both datasets show that comparing with Landsat 7, IKONOS overestimates negative NDVI values and slightly underestimates positive NDVI values





COTS Software Approach

Simulations of Landsat 7 images from IKONOS data have been also performed using the ENVI software, a commercial product, and the following algorithm:



CC resampling generates the best results, while the NN resampling – the worst

Results of such simulations are very similar to those generated with the PSF synthesis method.

Conclusions

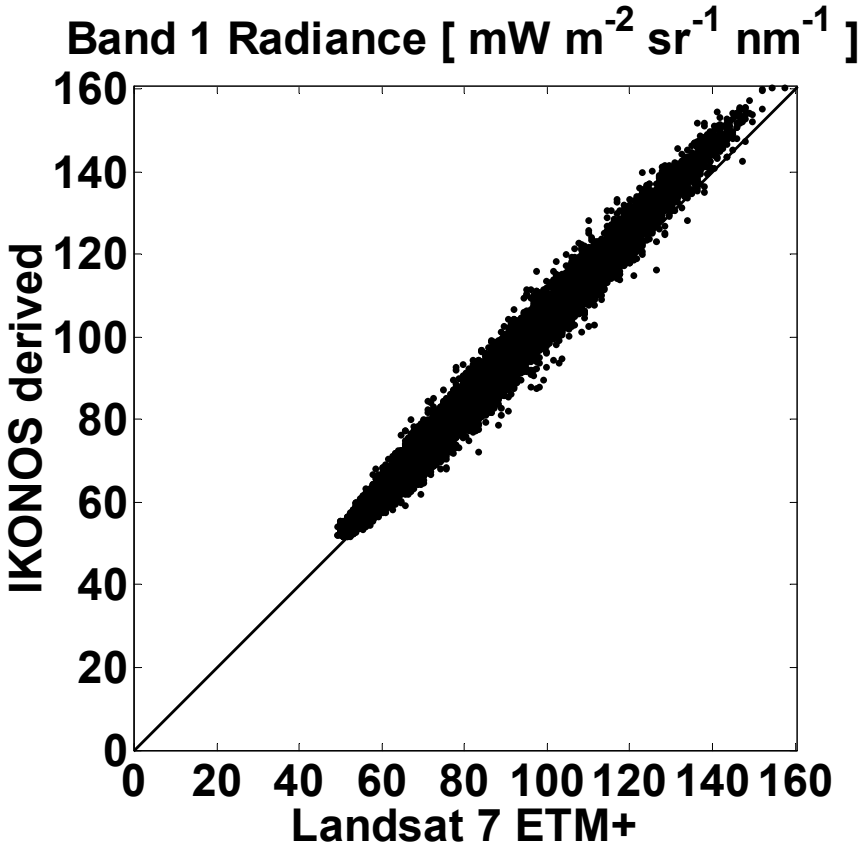
- Subsets of Landsat 7 ETM+ VNIR images can be simulated from IKONOS multispectral images
- Good co-registration of the simulated images with actual Landsat 7 images is achieved in some cases, but radiometry is often in disagreement
- Differences can be attributed to bi-directional reflectance effects (both in the atmosphere and on the ground)
- The largest effects are for images acquired at lower IKONOS viewing angles (~60°)
- These results emphasize a need for atmospheric correction
- The simulations can be conducted with commercial software using a combination of resampling, low-pass filtering, and subsampling

Acknowledgements

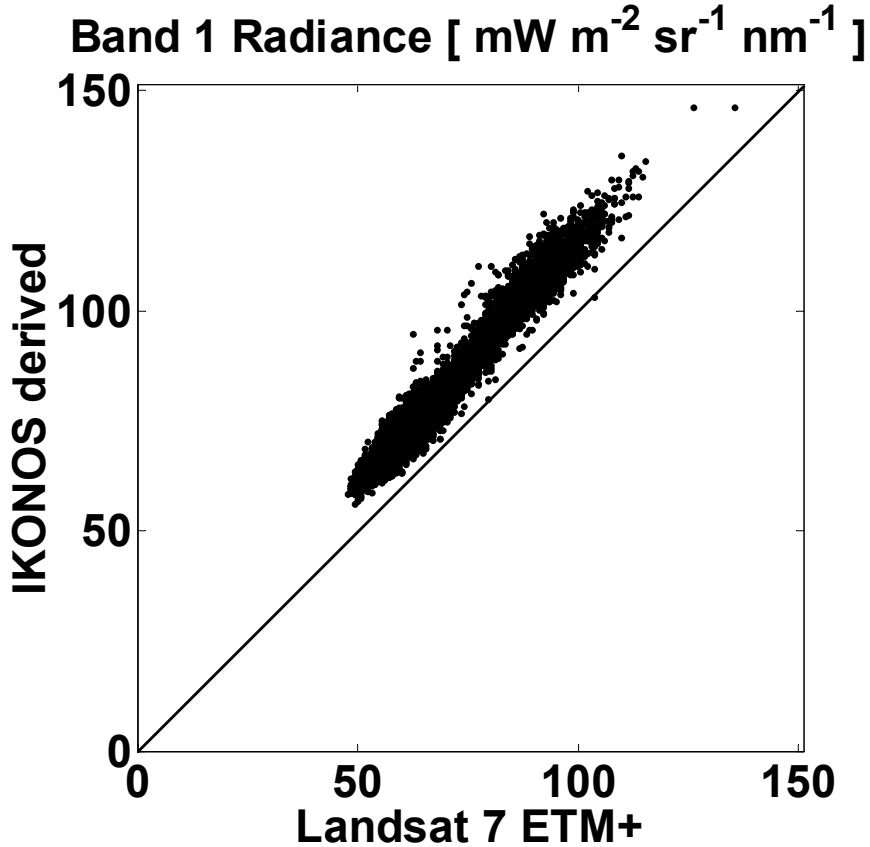
Mary Pagnutti	Lockheed Martin Space Operations Stennis Space Center, Mississippi
Robert Ryan	Lockheed Martin Space Operations Stennis Space Center, Mississippi
Robert Schowengerdt	University of Arizona Tucson, Arizona
Vicki Zanoni	NASA Earth Science Applications Directorate Stennis Space Center, Mississippi

Scatter Plot Comparison: Band 1

High Elevation

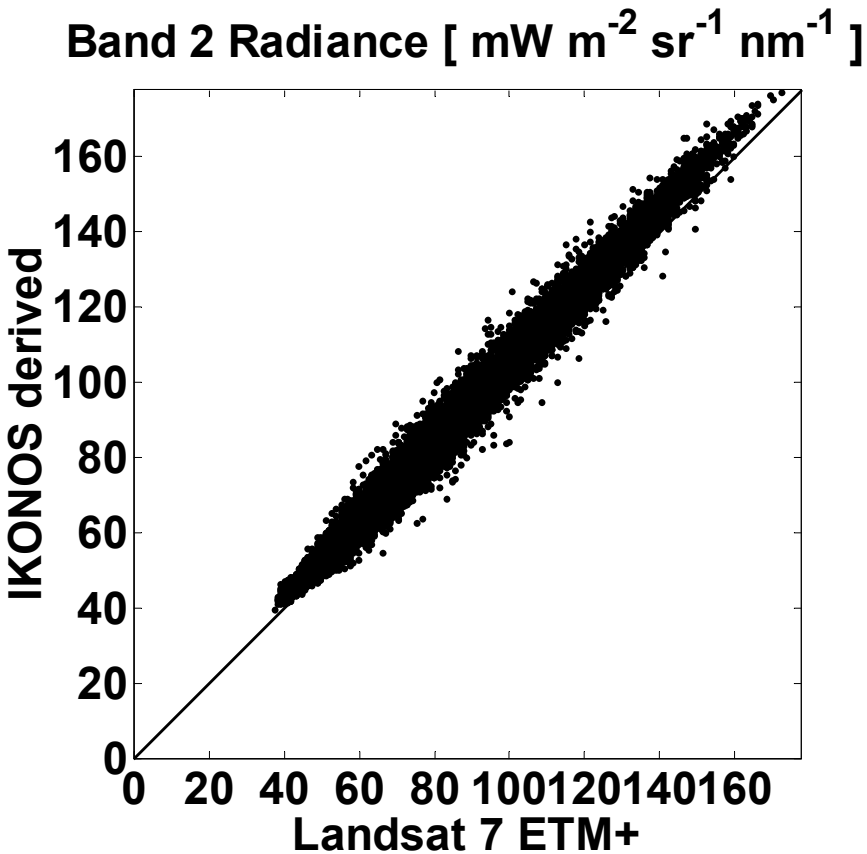


Low Elevation

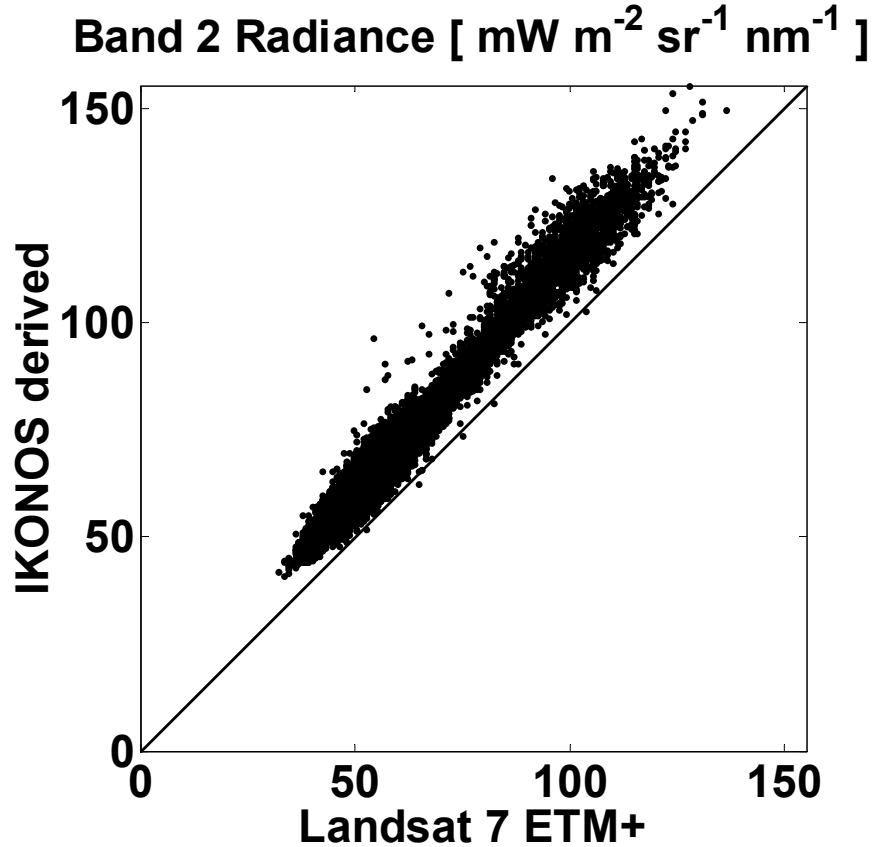


Scatter Plot Comparison: Band 2

High Elevation

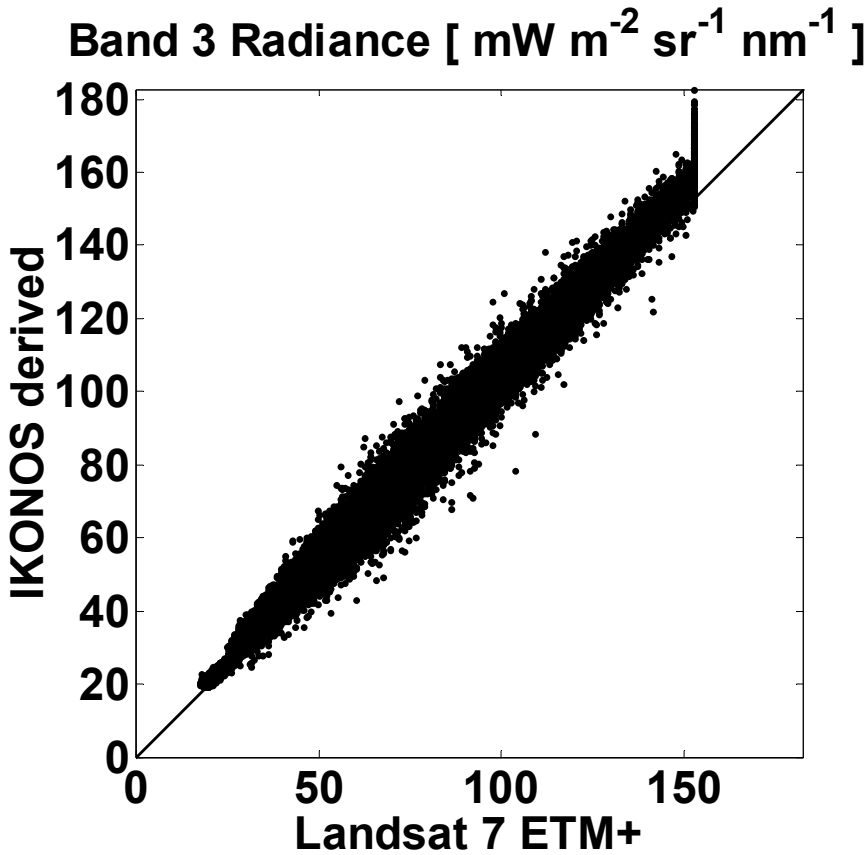


Low Elevation

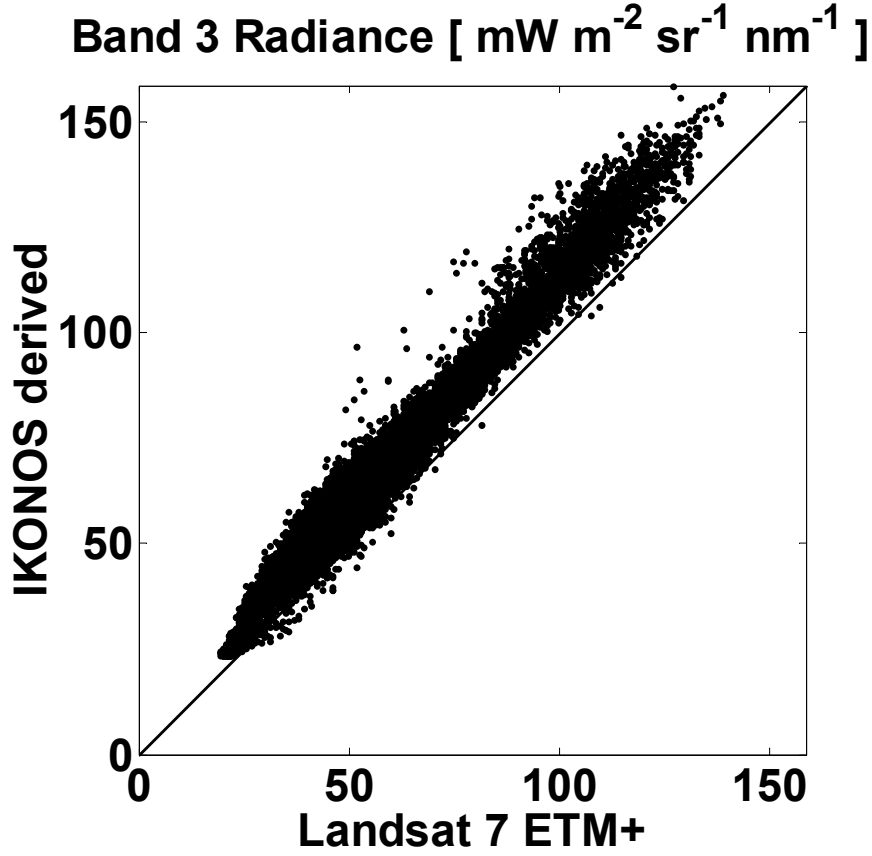


Scatter Plot Comparison: Band 3

High Elevation

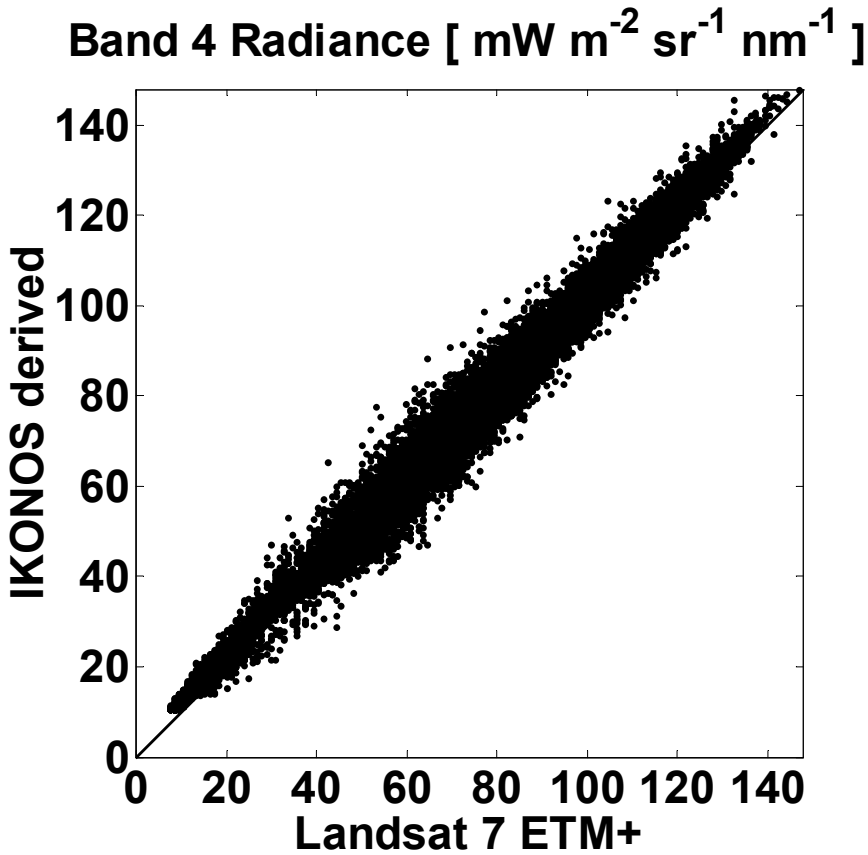
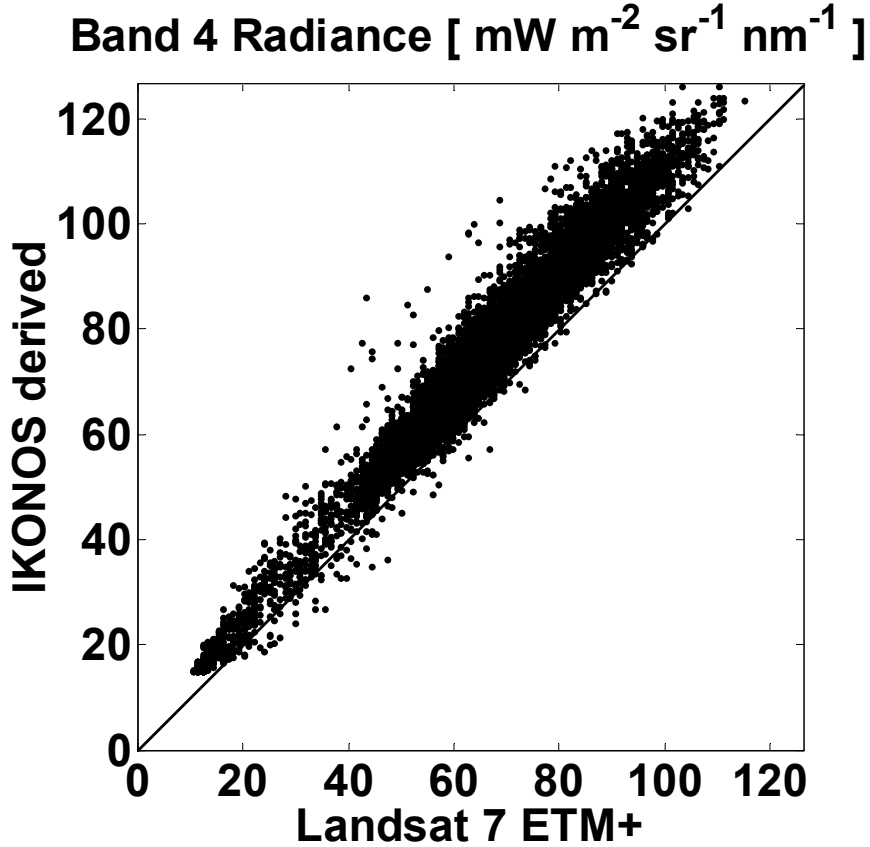


Low Elevation



Scatter Plot Comparison: Band 4

High Elevation



Low Elevation