EO-1 Hyperion Multispectral Band Synthesis

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OUTLINES

- Introduction
- Data and Methods
- Results
- Discussion & Concluding Remarks

INTRODUCTION

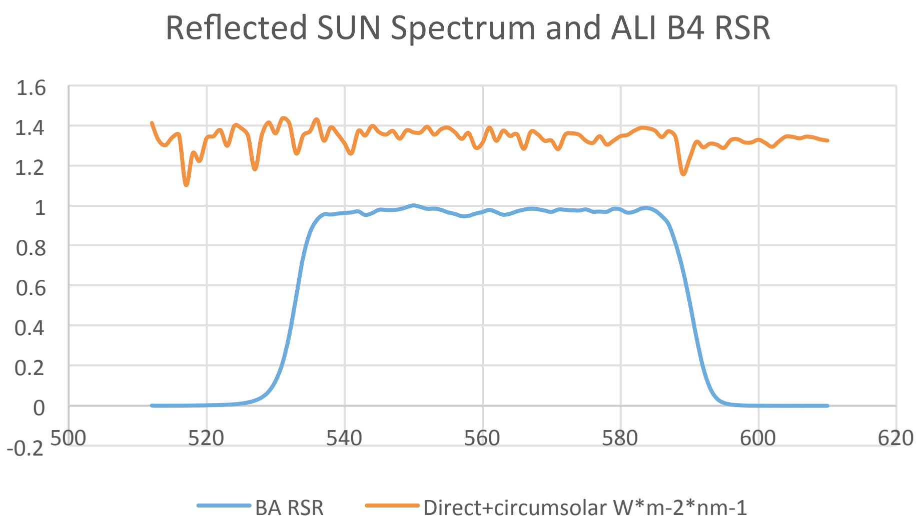
- Spectral band synthesis is a key step in the process of creating a simulated multispectral image from hyperspectral data (Blonski et al., 2003, NASA technical Report SE-2002-02-00012-SSC)
- Most methods synthesize a multispectral band by a weighted sum of hyperspectral bands, and they are different in their ways in determining the weighting factors (Khandelwal and Rajan, 2014, ISPRS Annals).
- The weights can be the values of the multispectral SRF (Green and Shimada, 1997), or obtained from the least square approximation of a multispectral SRF by a linear combination of the hyperspectral SRFs.
- This study compared the ways to determine the weights and investigated the factors causing the 'errors'.

EO-1 AND LANDSAT DATA

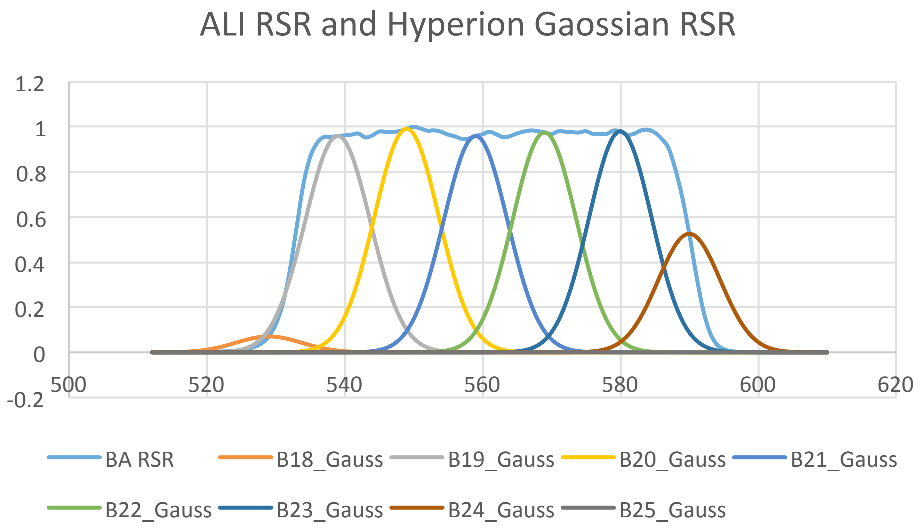
1) A site near the border between California and Nevada (041/034, 37.5°N, 117.3°W) with few vegetation covers. The EO-1 data were acquired on Oct 7, 2014.

2) Data acquired on August 2, 2001 in USDA Field Site (015, 033, 39.0^{O}N, 76.65^{O}W) by EO-1 and L-7 ETM+ in the Baltimore-Washington area. EO-1 sensor look angle was 1.99 degrees. The acquisition time difference between EO-1 and L-7 was less than 5 minutes.

METHOD



$$L_j = \int_{\lambda_1}^{\lambda_2} S(\lambda) RSF_j(\lambda) d\lambda / (\lambda_2 - \lambda_1)$$



Measurements of Hyperion bands:

$$H_i = \int S(\lambda) G_i(\lambda) d\lambda / FWHM_i$$

Synthesize an ALI band by Hyperion Bands:

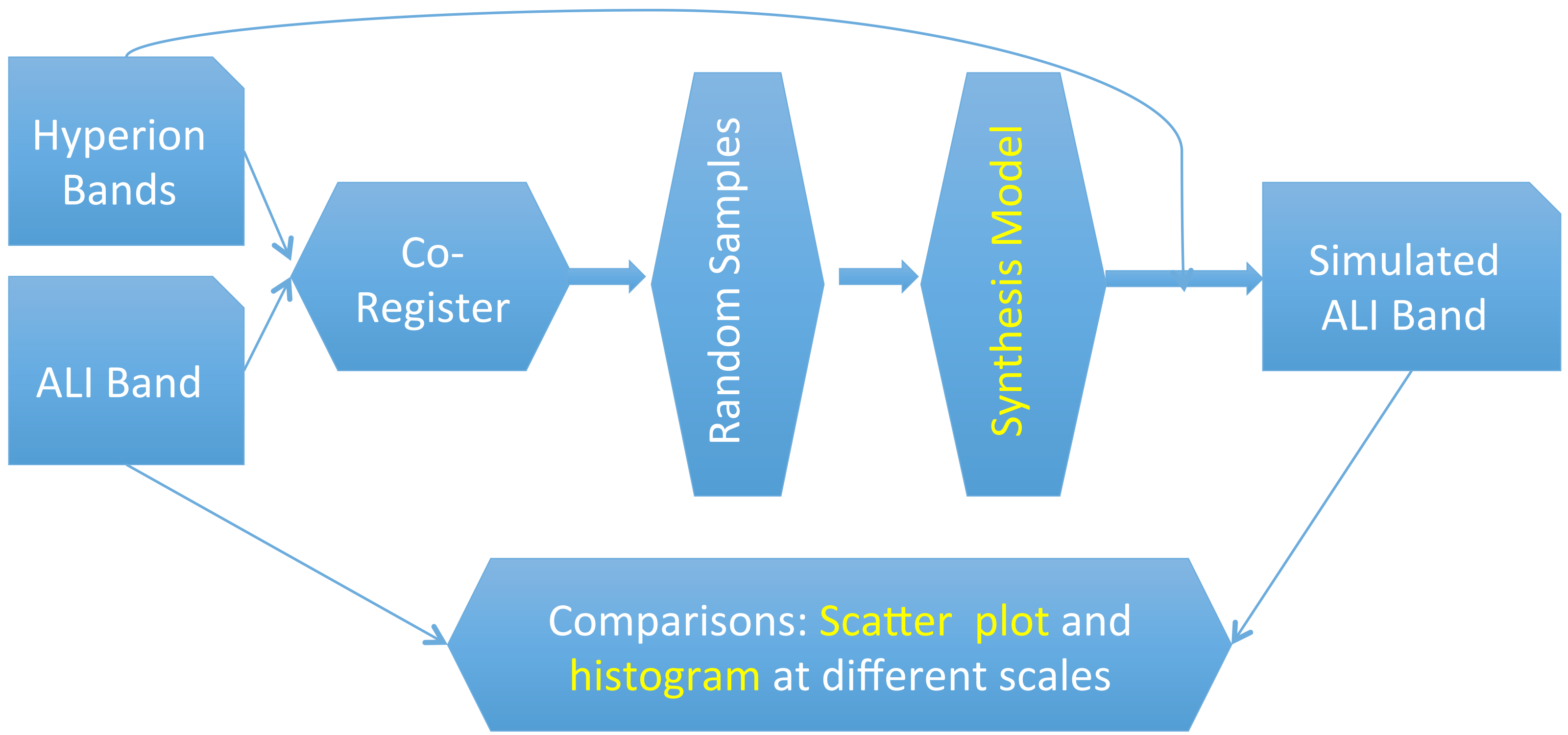
$$L_j \approx \sum_1^k (C_i H_i FWHM_i) / (\lambda_2 - \lambda_1)$$

To find the weight $\boldsymbol{C_i}$, i=1,2, …, k

DATA PROCESSING STEPS

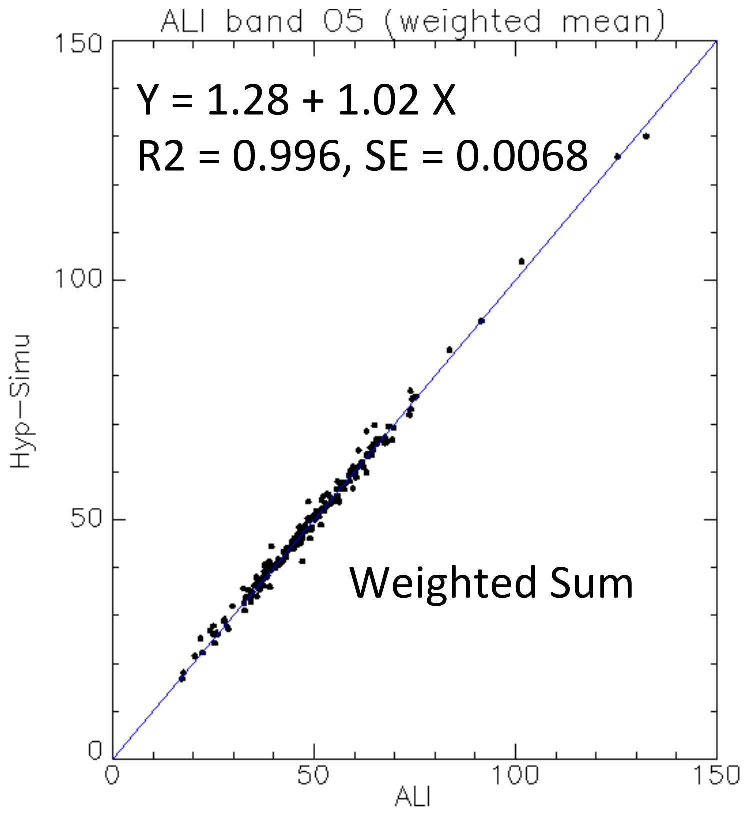
1) Convert image data to TOA Radiance, W/(m^2 SR nm)
2) Co-register Hyperion bands with multispectral data if necessary
3) Randomly pick some (200) samples from co-registered images
4) Build synthesis models (weighted sum; no-negative least-square)
5) Extract pixel values (30m and 90m) in common area (excluding edges)
6) Compare simulated data with ALI or ETM+ data using scatter plot (linear regression) and histograms

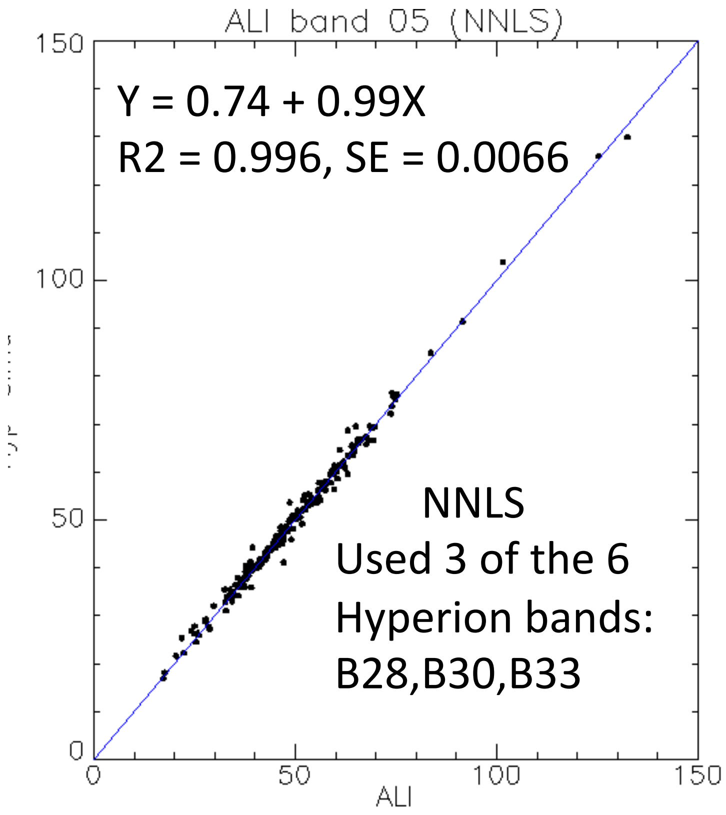
Synthesis of ALI bands from Hyperion Data in TOA Radiance

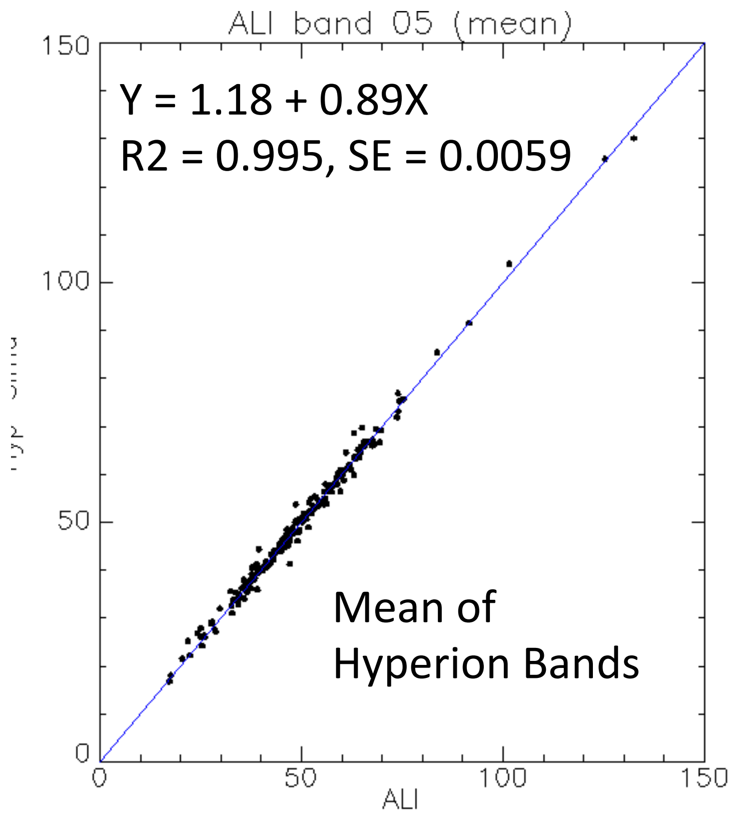


RESULTS

1) Weighted Sum and NNLS models gave similar good results (see plots)

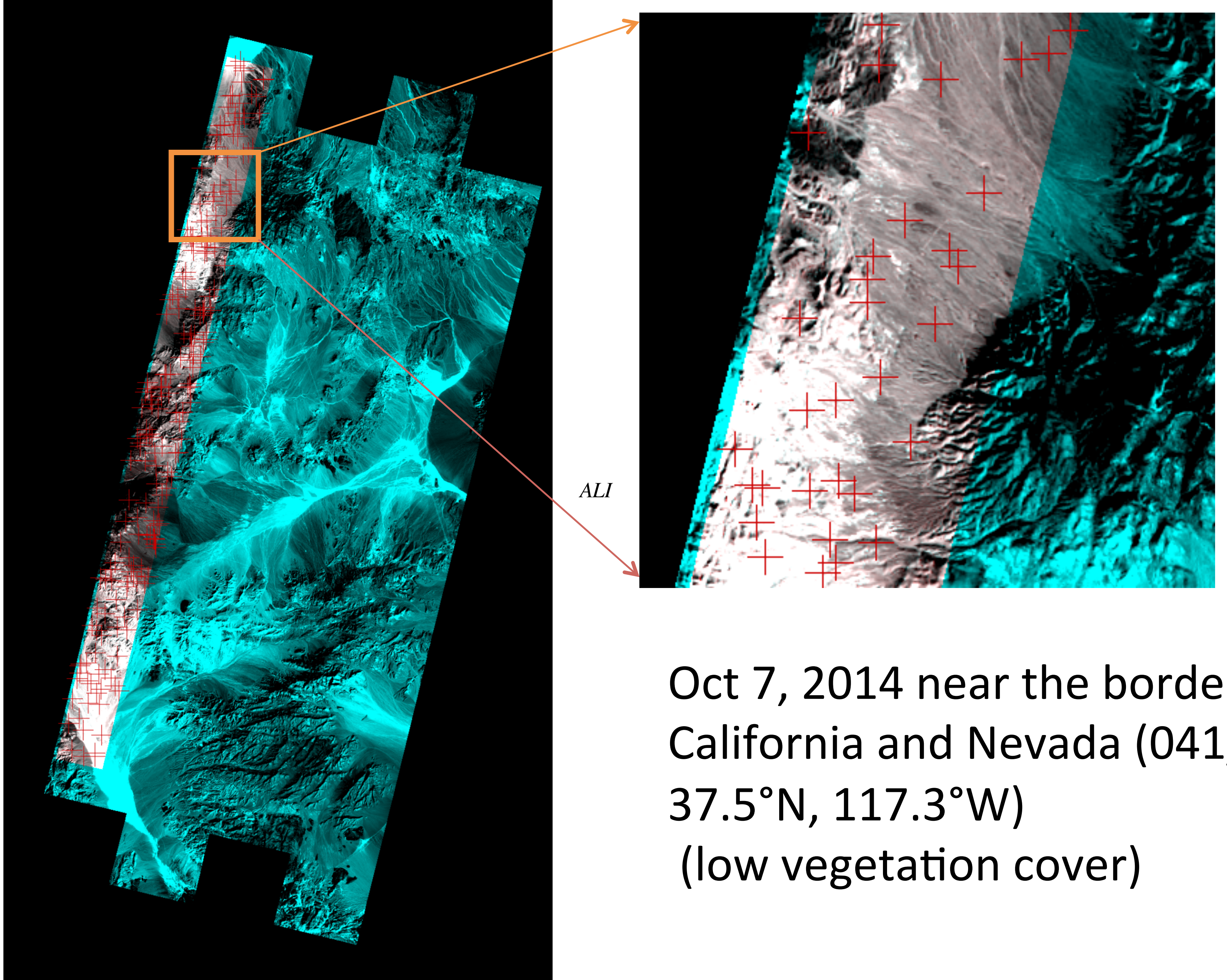




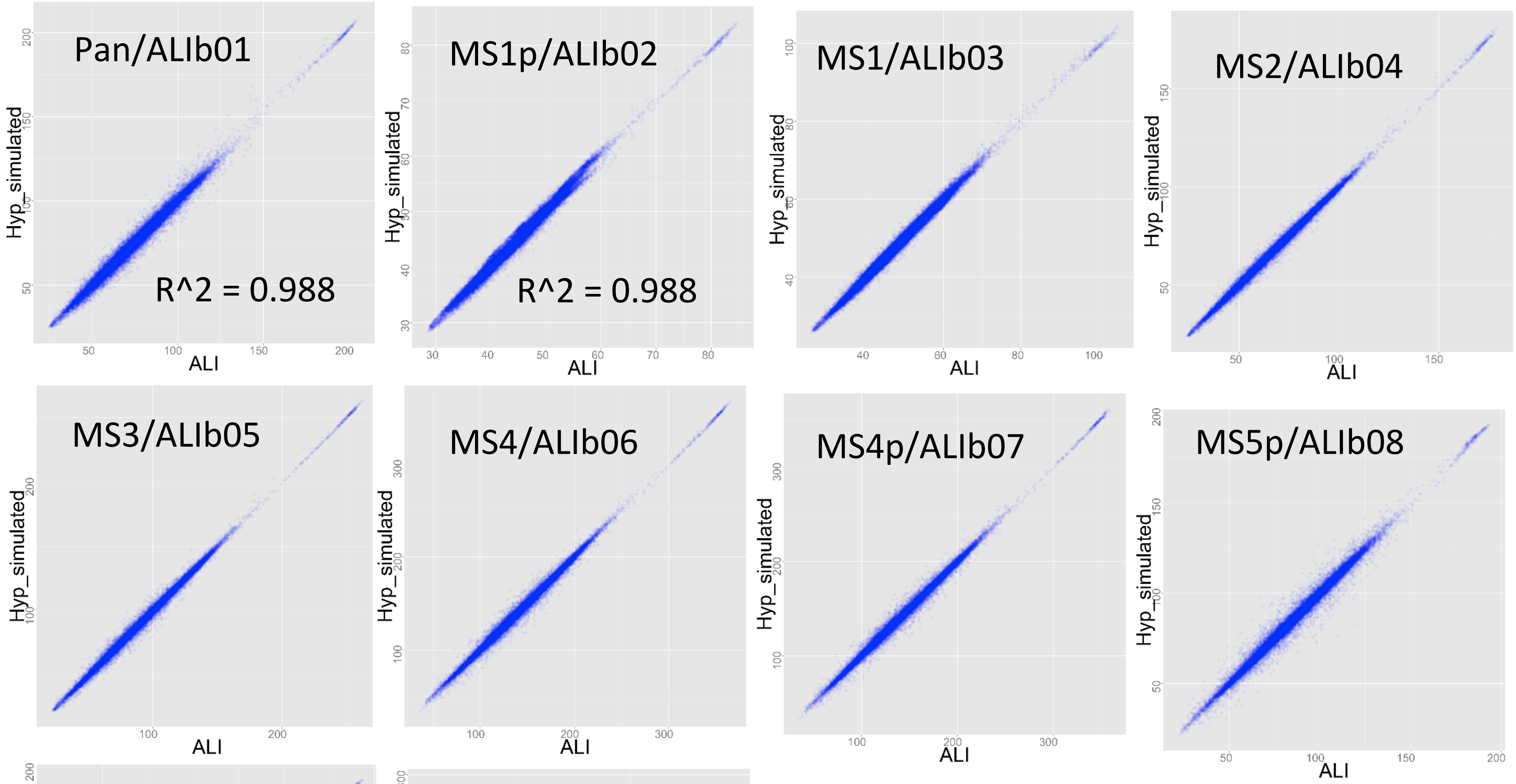


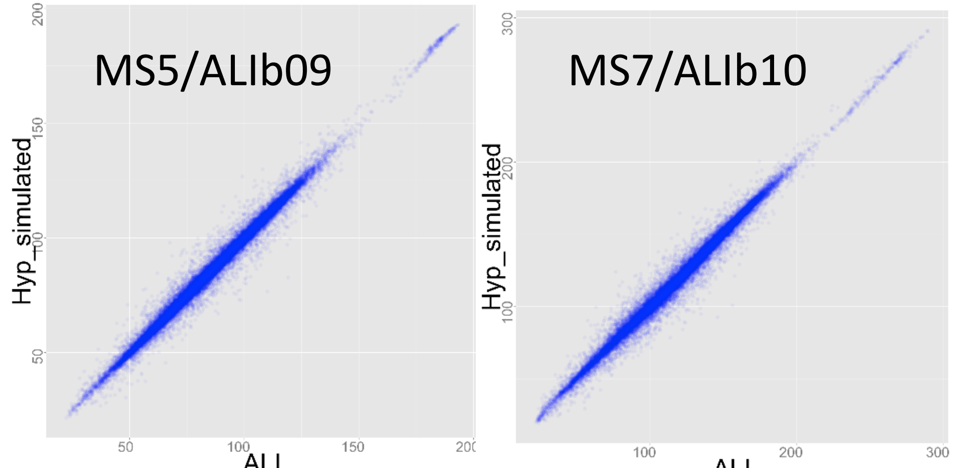
2) Better results for a site with less Vegetation cover

3) Good results for Synthesis of L-7 ETM+ bands



Oct 7, 2014 near the border between California and Nevada (041/034, 37.5°N, 117.3°W)
(low vegetation cover)





Hyperion and ALI data acquired on Oct. 7, 2014 (041/034, 37.5°N, 117.3°W).

Scatter plots - Comparison of all pixels in common area at 90m scale

R-square is from 0.984 to 0.995

RMSE from 0.709 to 4.776 W/m2/nm/Sr

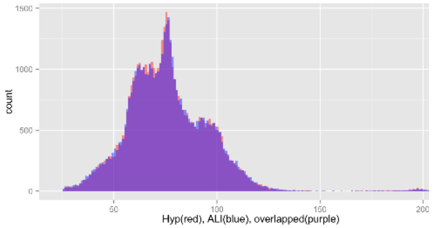
Regression relation between ALI (Y) and simulated from Hyperion (X): $Y=B0 + B1 * X$ from all 90m pixels in the overlapped area of these two sensors

EO-1 ALI Band	R^2	B0	B1	RMSE
1	0.985	1.81	0.97	2.518
2	0.988	0.73	0.98	0.709
3	0.991	0.61	0.99	0.847
4	0.995	0.62	0.99	1.241
5	0.995	0.57	0.99	1.895
6	0.994	1.34	0.99	2.888
7	0.994	0.66	0.995	2.962
8	0.987	0.95	0.99	2.424
9	0.984	9.84	0.93	4.776
10	0.985	2.40	0.98	3.910

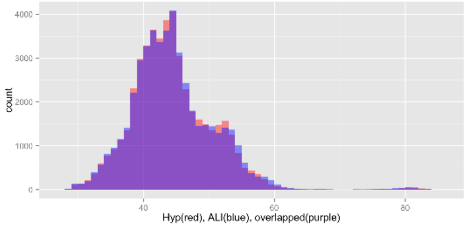
Comparisons of Histograms

RED – Hyperion_synthesized, BLUE – ALI, Purple - overlapped

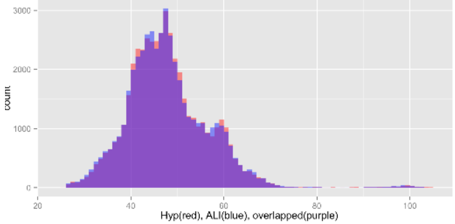
Pan/ALIb01



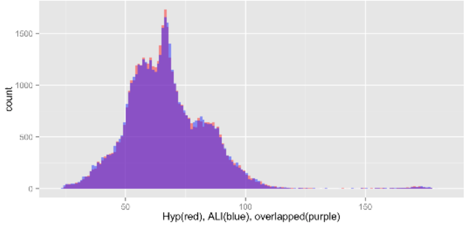
MS1p/ALIb02



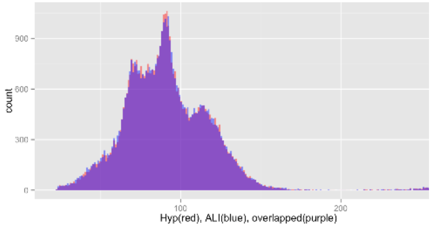
MS1/ALIb03



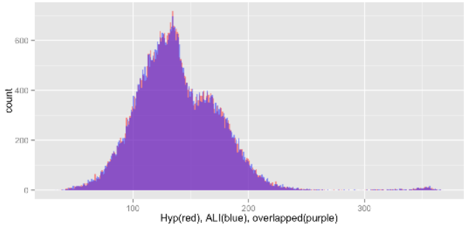
MS2/ALIb04



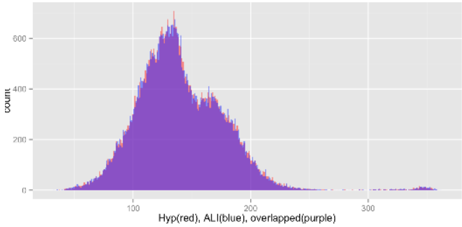
MS3/ALIb05



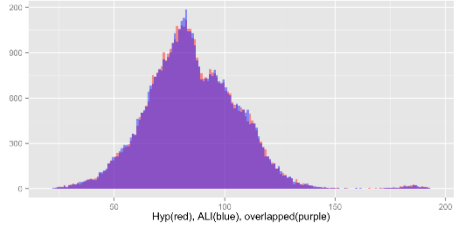
MS4/ALIb06



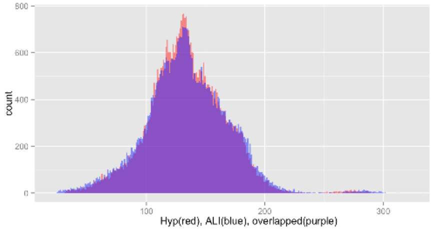
MS4p/ALIb07



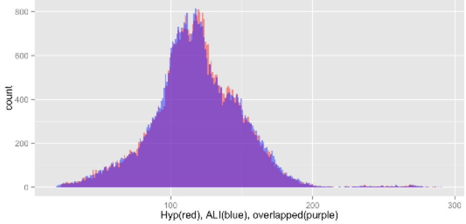
MS5p/ALIb08



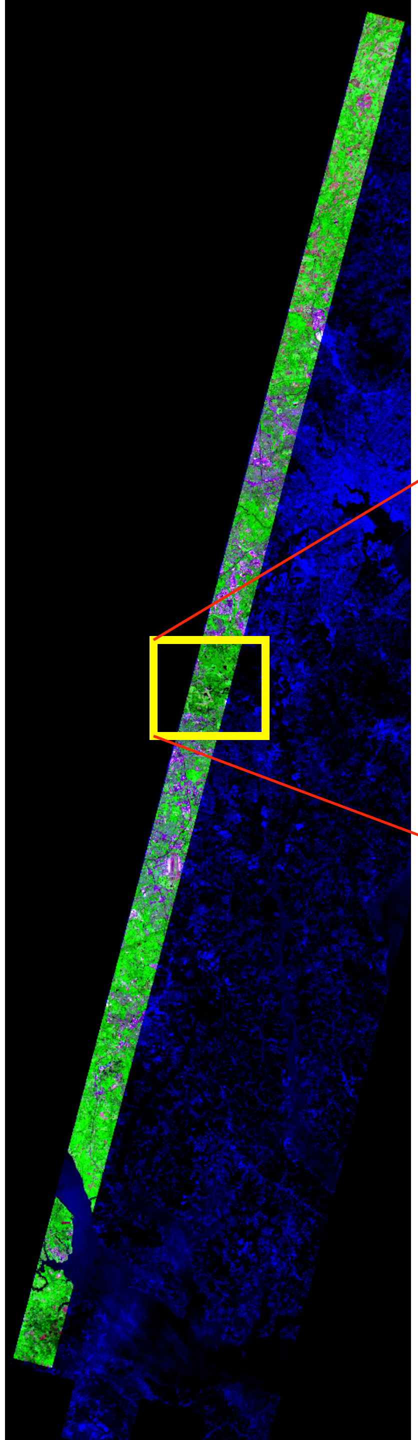
MS5/ALIb09

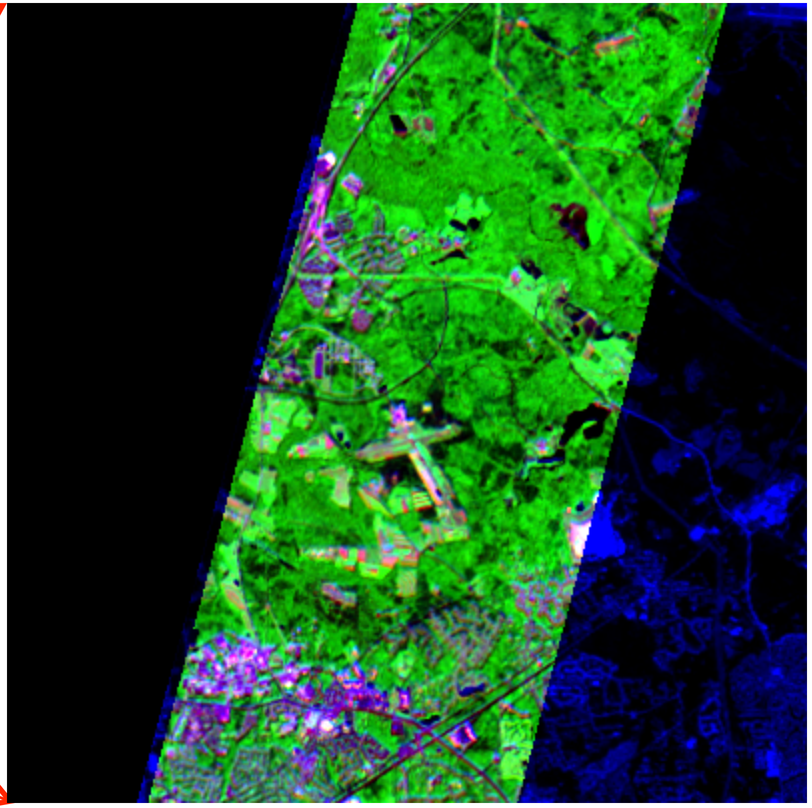


MS7/ALIb10

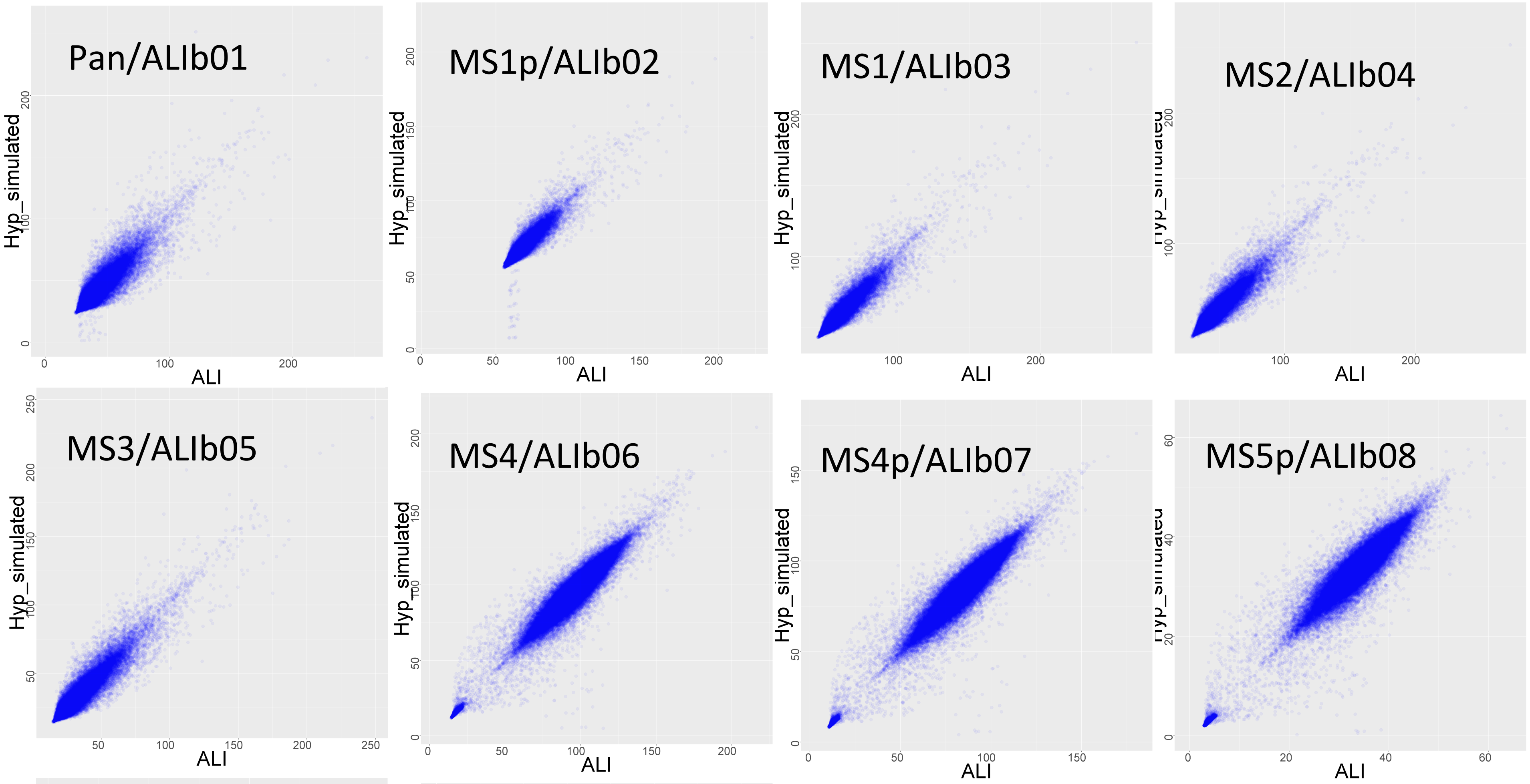


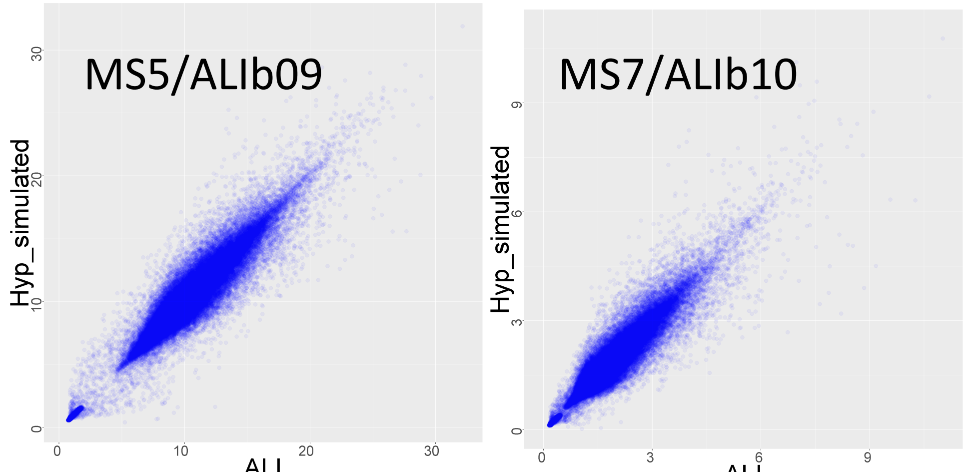
Hyperion and ALI data acquired on Oct. 7, 2014 (041/034, 37.5°N, 117.3°W). Histograms - Comparison of all pixels in common area at 90m scale





EO-1 ALI and Hyperion Data
August 2, 2001 at USDA Field Site
(015/033, 39.0^{O}N, 76.65^{O}W)





Hyperion and ALI data acquired on Aug. 2, 2001, 015/033 (38°58'N, 76°41'W)

Scatter plots - Comparison of all pixels in common area at 90m scale

R^2: 0.853 to 0.945

RMSE: 0.27 – 4.70 W/m2/nm/Sr

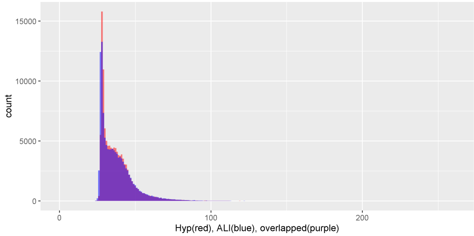
Regression relation between ALI (Y) and simulated from Hyperion (X): Y=B0 + B1 * X from all 90m pixels in the overlapped area of these two sensors.

EO-1 ALI Band	R^2	B0	B1	RMSE
1	0853	4.70	0.88	4.66
2	0.895	5.93	0.91	2’31
3	0.912	4.02	0.93	2.87
4	0.906	2.75	0.94	3.51
5	0.910	1.98	0.93	3.90
6	0.944	4.78	0.95	5.14
7	0.945	4.25	0.95	4.70
8	0.940	1.80	0.95	1.94
9	0.913	0.65	0.94	0.93
10	0.899	0.11	0.94	0.27

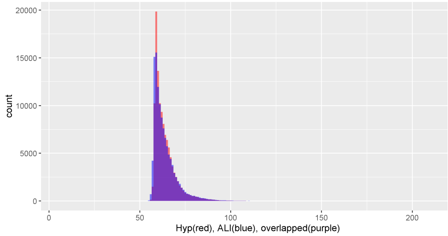
Comparisons of Histograms

RED – Hyperion_synthesized, BLUE – ALI, Purple - overlapped

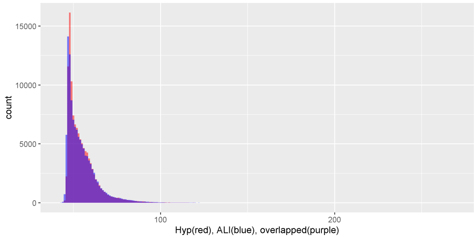
Pan/ALIb01



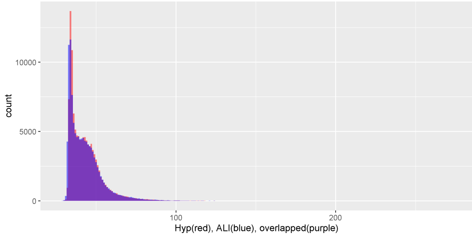
MS1p/ALIb02



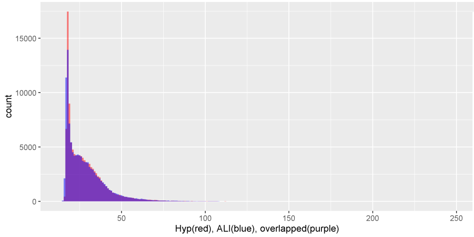
MS1/ALIb03



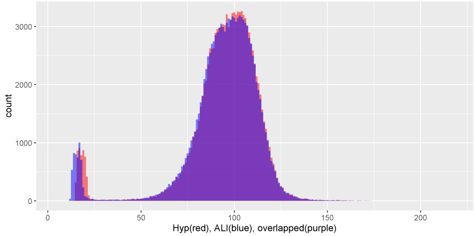
MS2/ALIb04



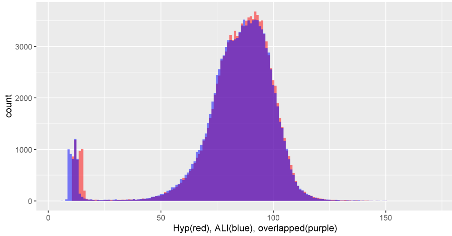
MS3/ALIb05



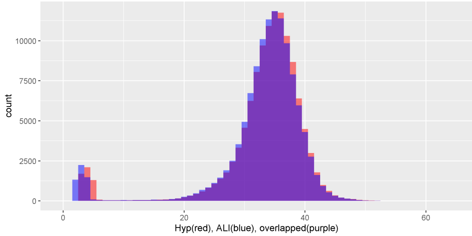
MS4/ALIb06



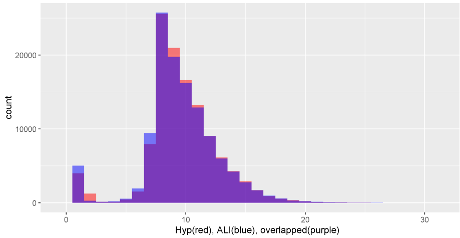
MS4p/ALIb07



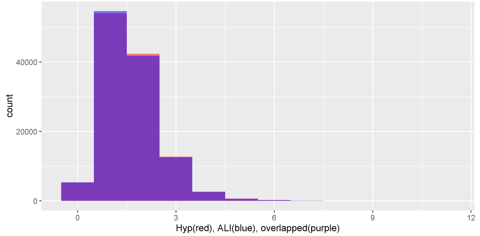
MS5p/ALIb08



MS5/ALIb09



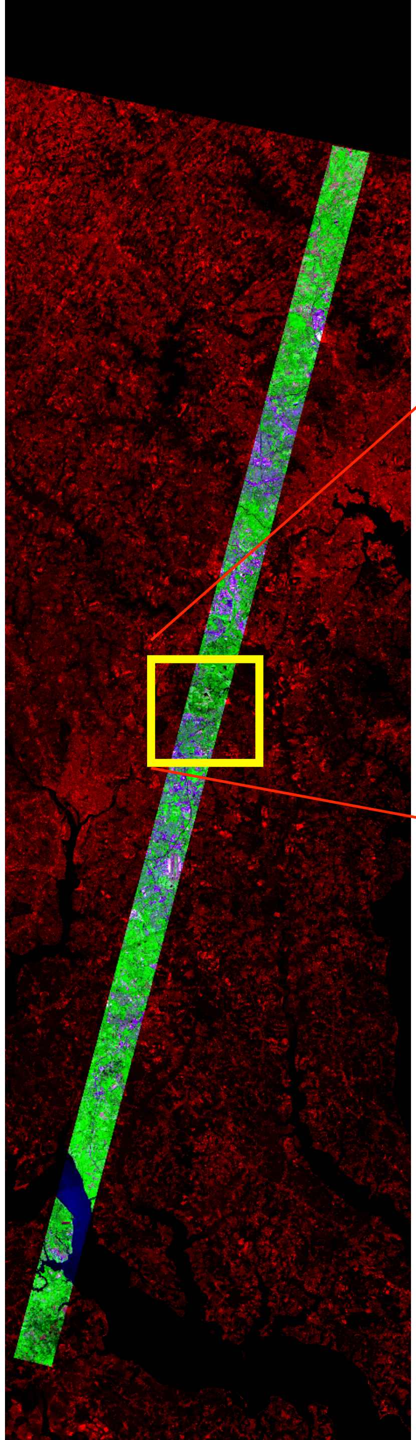
MS7/ALIb10

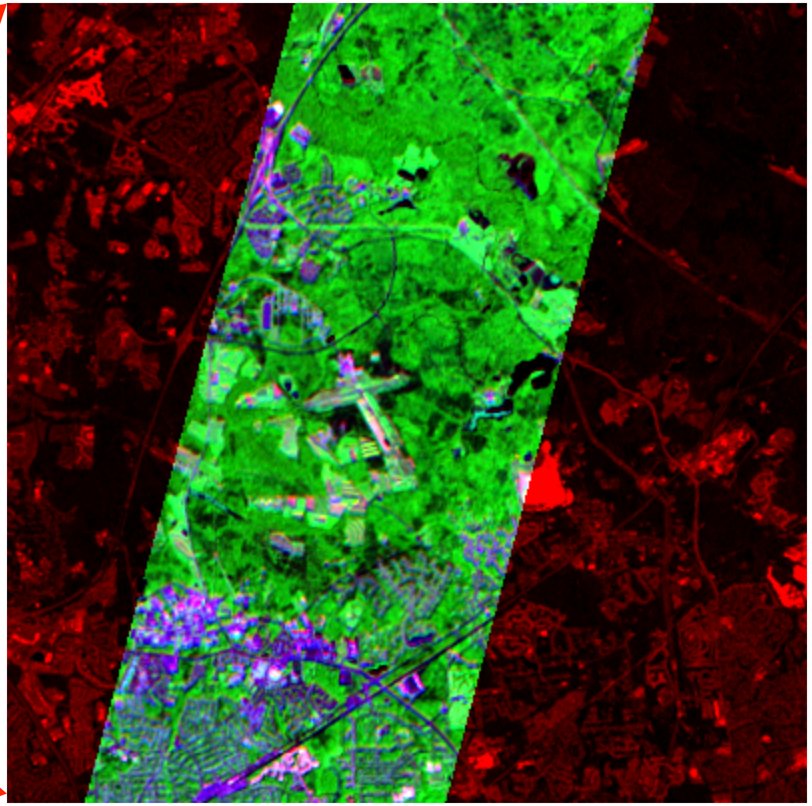


Hyperion and ALI data acquired on Aug. 2, 2001, 015/033 (38°58’N, 76°41’W)
Histograms - Comparison of all pixels in common area at 90m scale

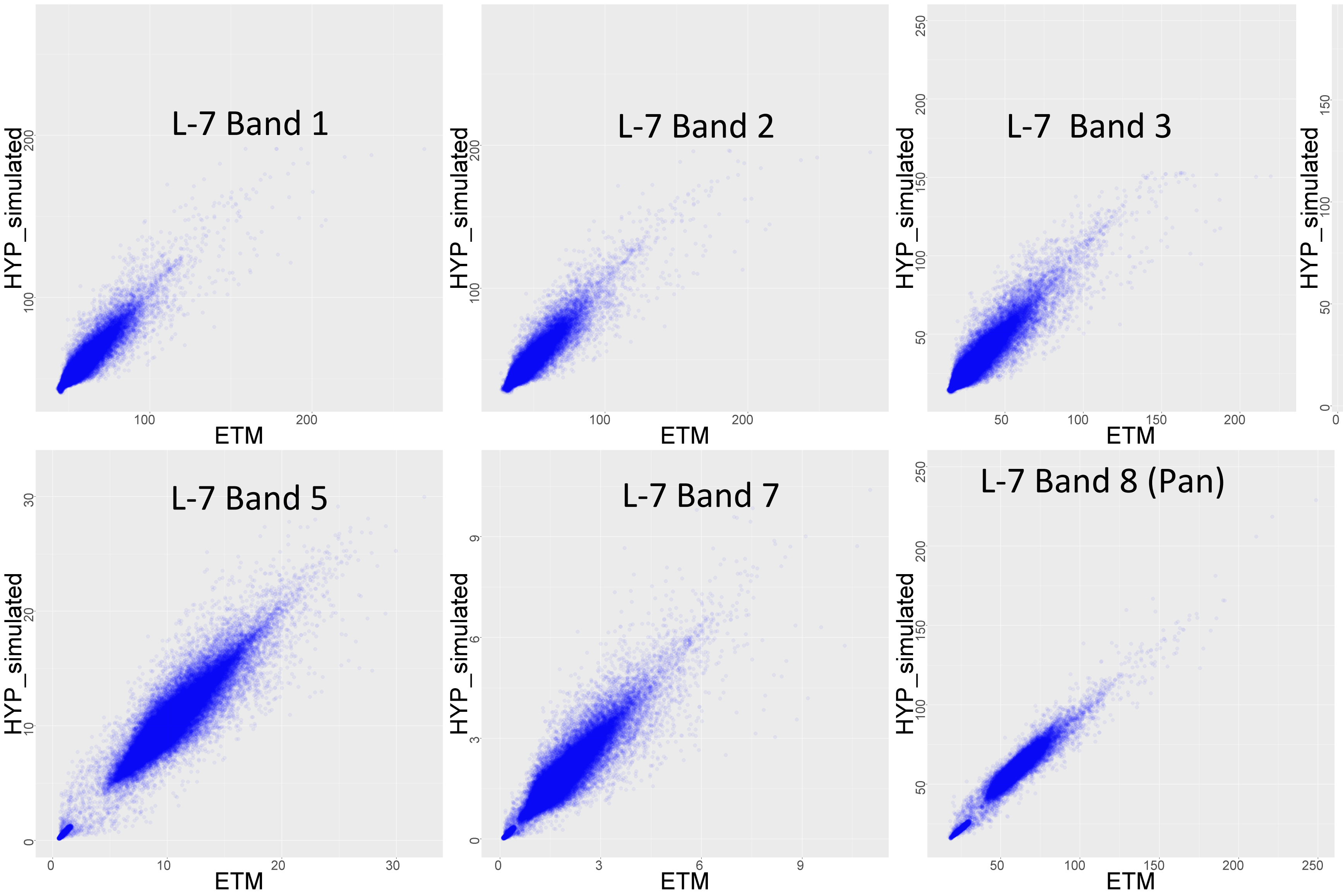
Mean and STDV of ALI images and images synthesized from Hyperion Data

	ALI		Hyperion-synthesis	
	Mean	Stdev	Mean	Stdev
Band 1	37.190842	14.19581	37.71978	12.56135
Band 2	63.266628	9.523947	63.88015	7.398989
Band 3	54.60738	11.10989	54.94302	10.19258
Band 4	43.097276	12.314866	43.4335	12.27166
Band 5	28.472531	14.16343	28.54542	13.82813
Band 6	93.476101	22.824957	93.98881	22.43556
Band 7	82.548213	21.400519	83.29037	20.60969
Band 8	32.70203	8.627903	33.15726	8.063243
Band 9	9.501321	3.493637	9.651221	3.294028
Band 10	1.624648	0.925845	1.653536	0.894452





EO-1 Hyperion and L-7 ETM+ Data
August 2, 2001 at USDA Field Site
(015/033, 39.0^{O}N, 76.65^{O}W)



Hyperion and ETM+ data acquired on Aug. 2, 2001, 015/033 (38°58’N, 76°41’W)

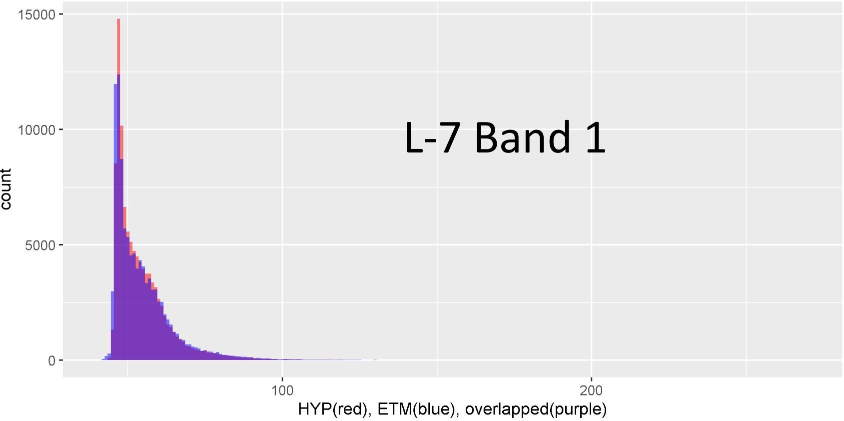
Scatter plots - Comparison of all pixels in common area at 90m scale

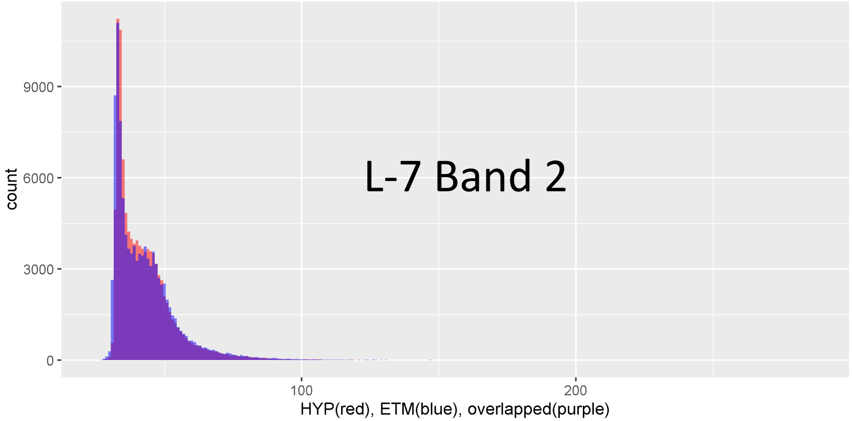
R^2: 0.883 to 0.938

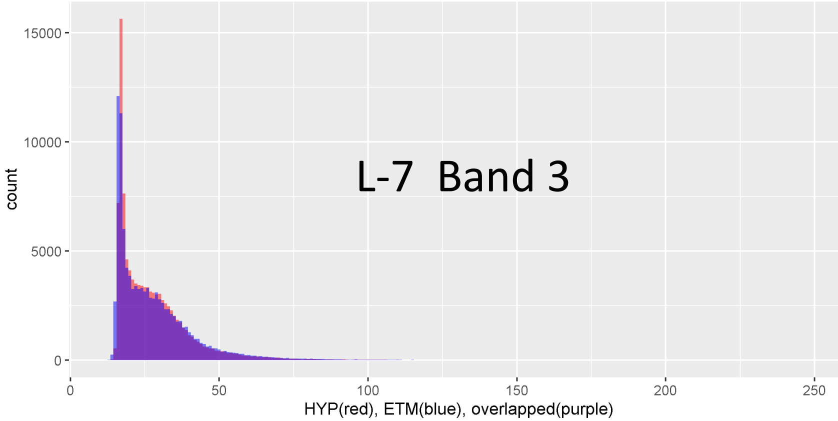
RMSE: 0.30 – 5.10 W/m2/nm/Sr

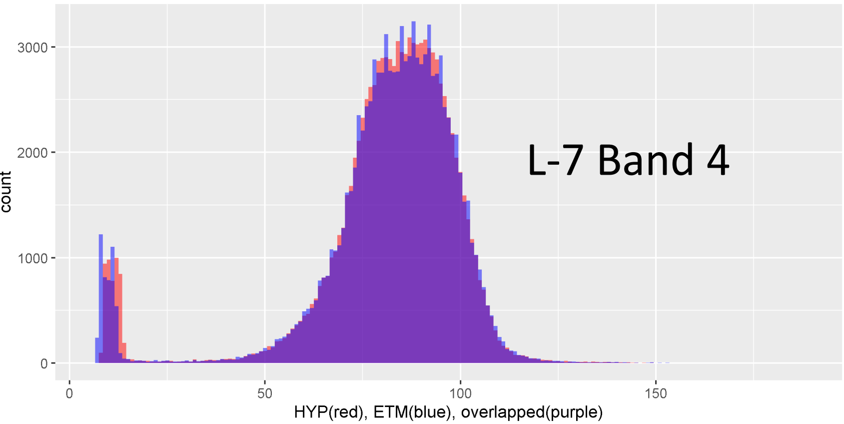
Regression relation between ETM+ (Y) and simulated from Hyperion (X): Y=B0 + B1 * X from all 90m pixels in the overlapped area of these two sensors.

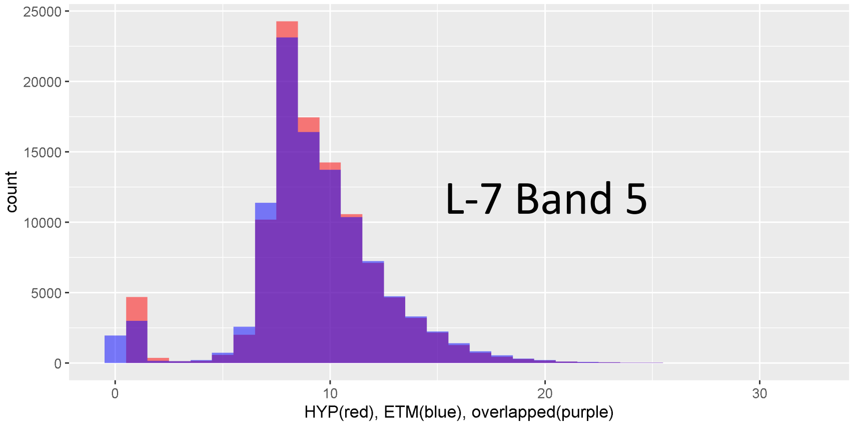
L-7 ETM+ Band	R^2	B0	B1	RMSE
1	0885	4.60	0.89	4.15
2	0.892	2.67	0.89	4.55
3	0.938	3.65	0.96	5.10
4	0.900	0.87	0.91	1.03
5	0.883	0.18	0.89	0.30
7	0.928	3.17	0.94	2.90
8	0.890	6.05	0.88	3.47





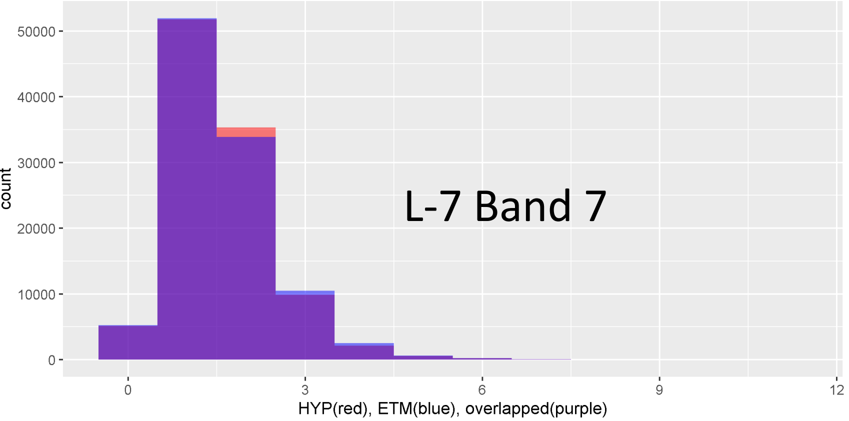


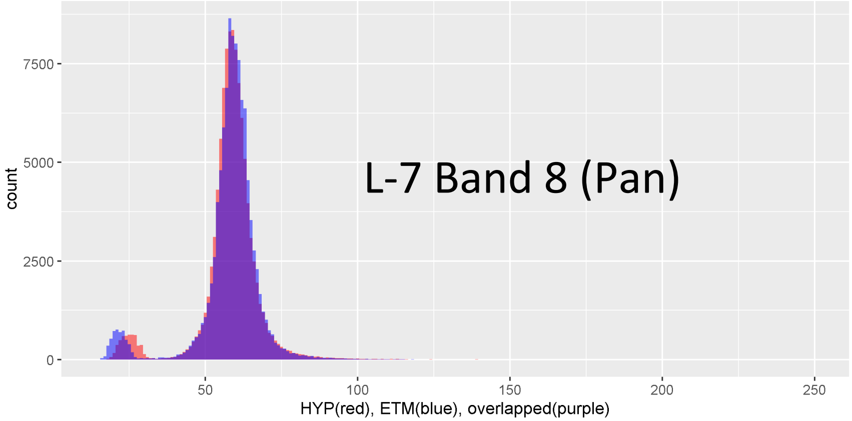


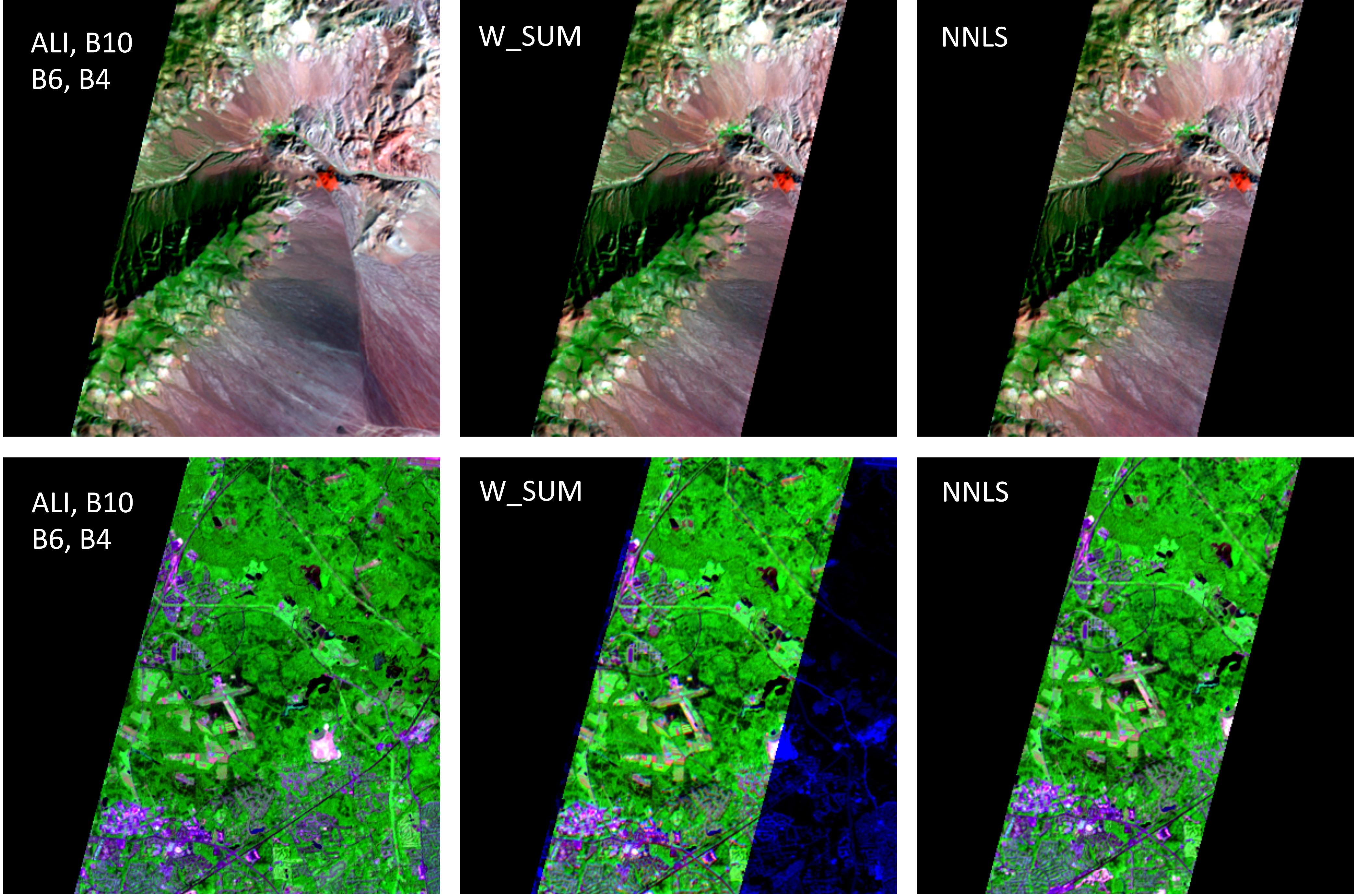


L-7 and ALI data acquired on Aug. 2, 2001, 015/033 (38°58’N, 76°41’W)

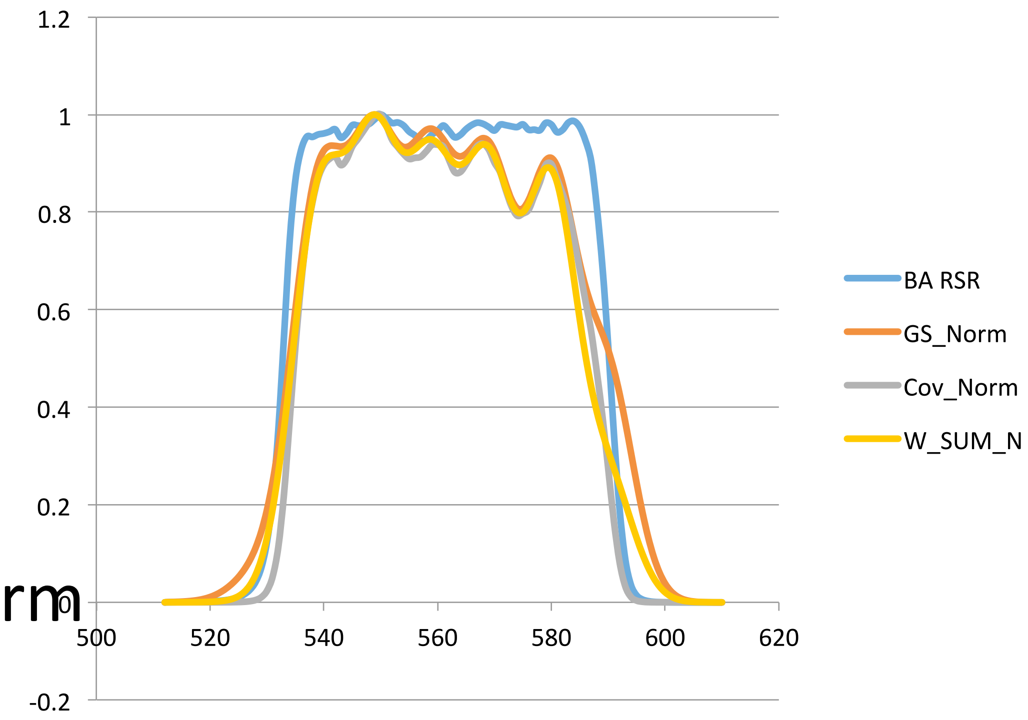
Histograms - Comparison of all pixels in common area at 90m scale






ALI, B10
B6, B4
W_SUM
NNLS
ALI, B10
B6, B4
W_SUM
NNLS

ERROR SOURCES



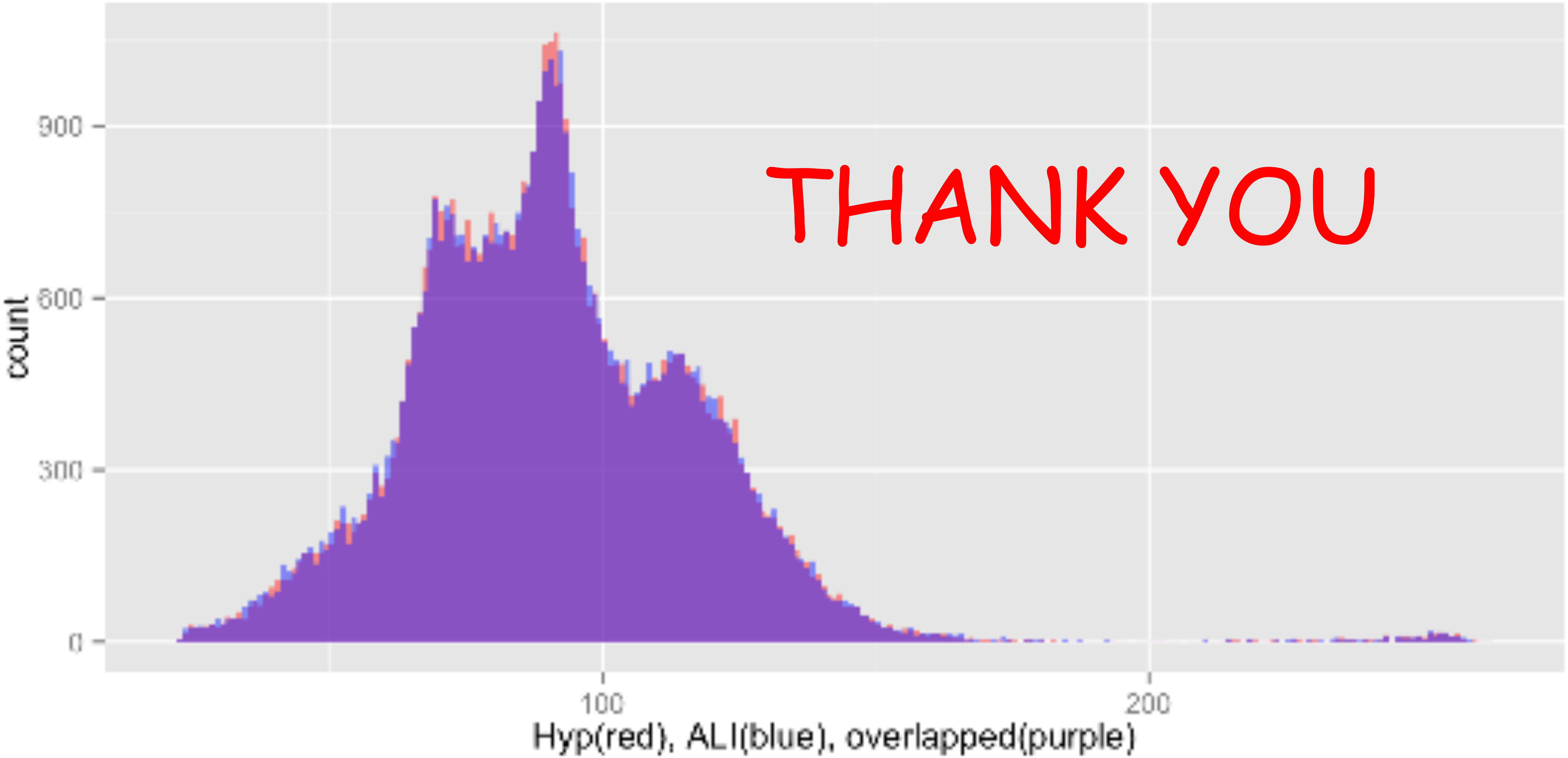
1) Limited sampling by Hyperion – never get perfect match (see graph). The spectrum of incoming radiance is the item we would like to measure. Without it we couldn't perform complete convolution.
2) The spectrum of incoming radiance is different for different targets. Using one model for all pixels in an image causes error
3) Spatial sampling of the scene was different in Hyperion and multispectral images, which caused the spreading of the scatter plots. Accurate spatial co-registration reduces the error.

CONCLUDING REMARKS

The synthesized pixel values using a simple model such as weighted_sum were very close to the pixel values of the multispectral bands to be simulated. After the gain and offset was determined and the synthesized data were calibrated, it explained 99% (at dry, non-vegetated site) and 90% (at site with Complex landuse covers) of the variance of the multispectral bands.

The hyperspectral data is very useful for systematic study of the multispectral data properties through band synthesis.

THANK YOU



count
900
600
300
0
100
200
Hyp(red), ALI(blue), overlapped(purple)