A Surface Reflectance product for Landsat/LDCM: Summary of activities, future work and implications for similar class sensors e.g. Sentinel 2

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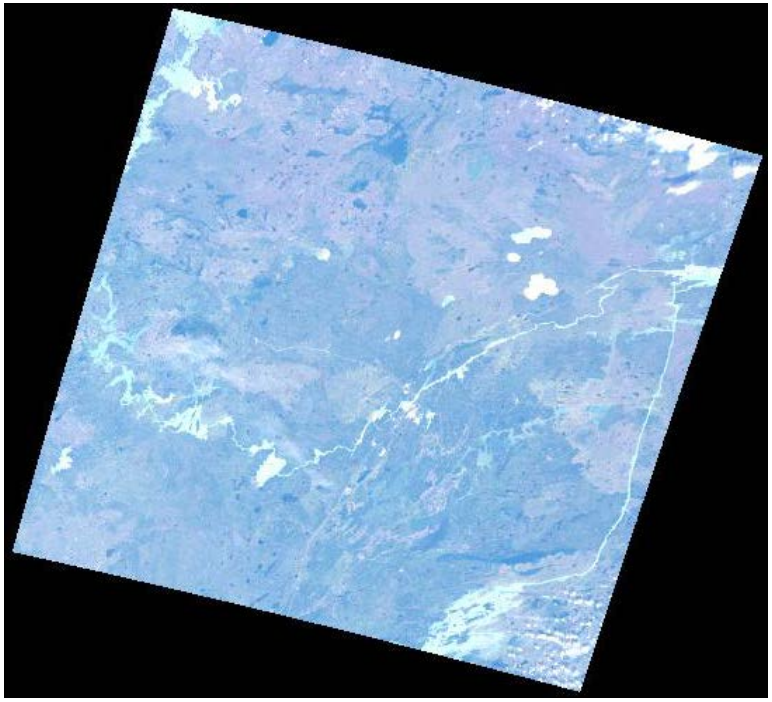
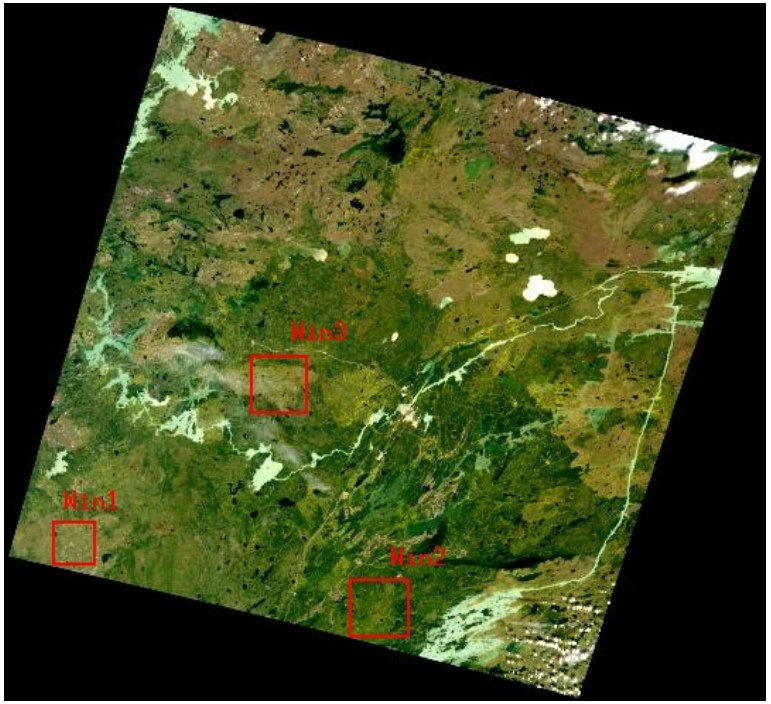
The need for Surface Reflectance
BOREAS ETM+ scene

Scene: p033r021
Date: 09/17/2001

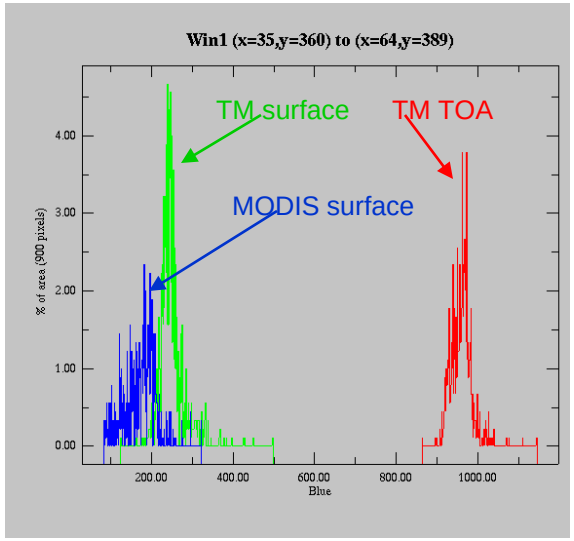


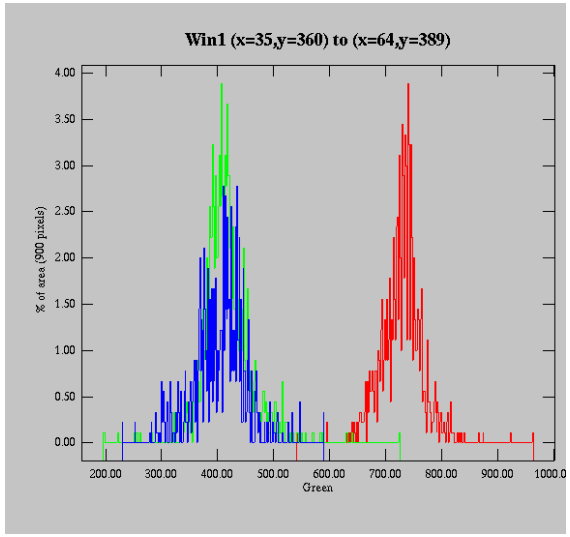
Top-of-atmosphere TOA

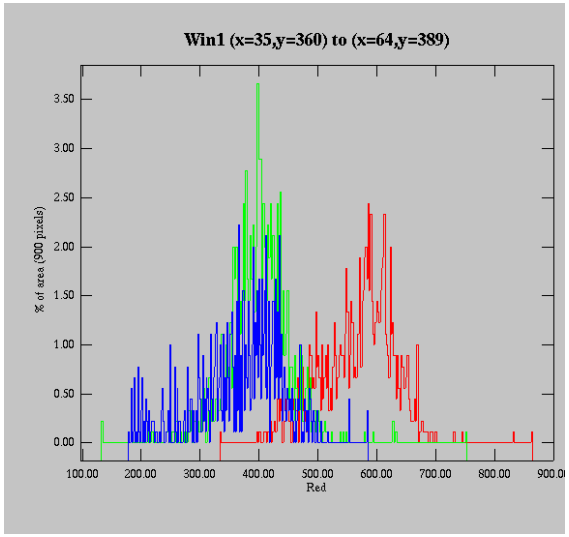


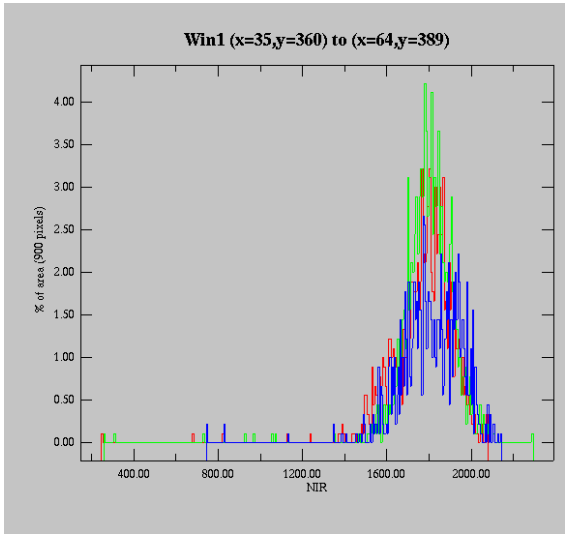
Surface Reflectance

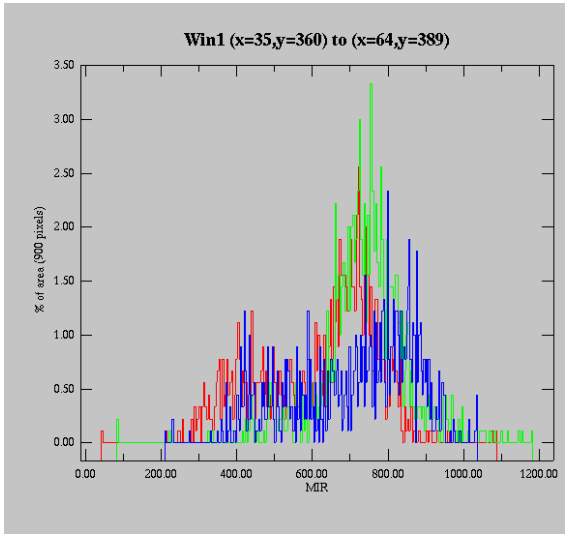
Window 1


Win1 (x=35,y=360) to (x=64,y=389)
TM surface
TM TOA
MODIS surface
% of area (900 pixels)
Blue

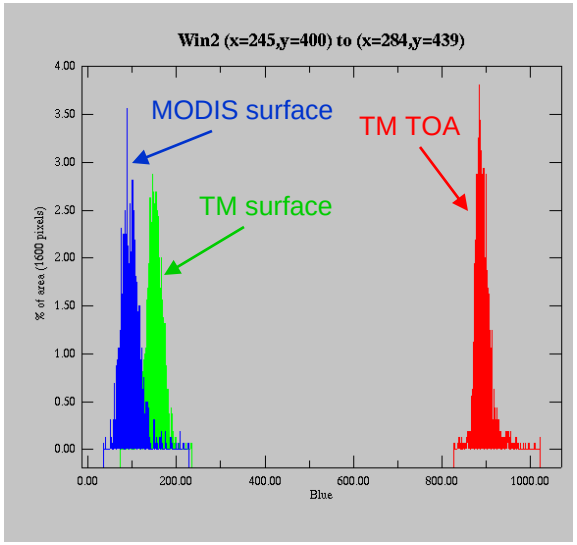

Win1 (x=35,y=360) to (x=64,y=389)
% of area (900 pixels)
Green

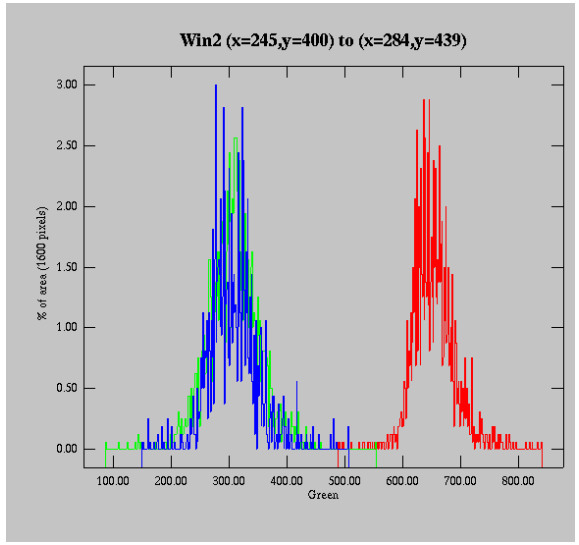

Win1 (x=35,y=360) to (x=64,y=389)
% of area (900 pixels)
Red

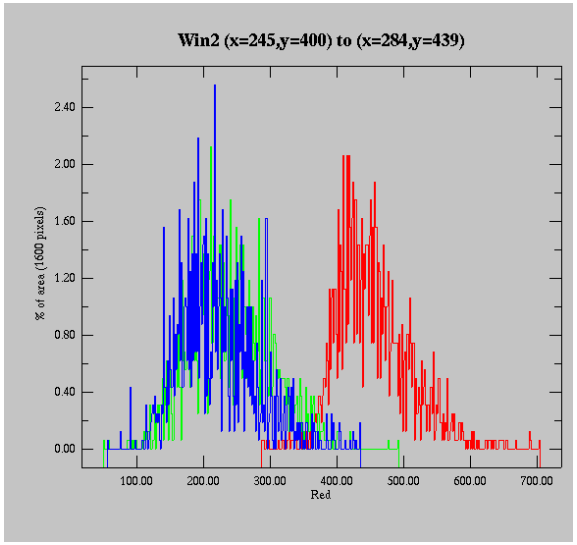

Win1 (x=35,y=360) to (x=64,y=389)
% of area (900 pixels)
NIR

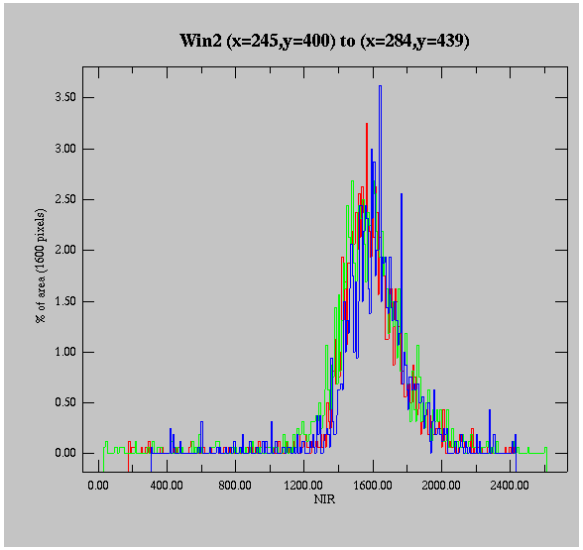

Win1 (x=35,y=360) to (x=64,y=389)
% of area (900 pixels)
MIR

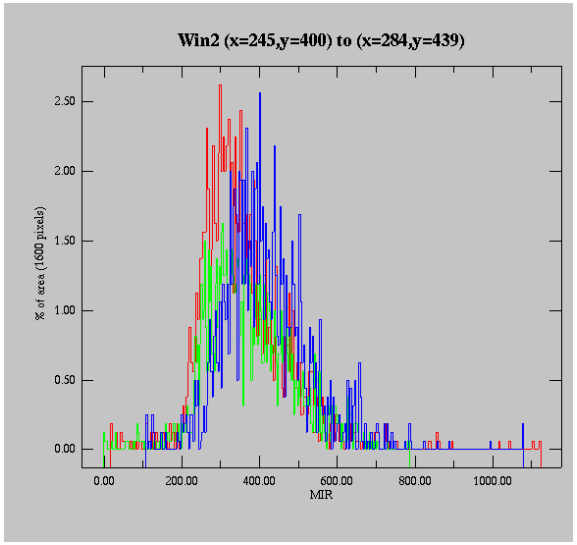
Window 2


Win2 (x=245,y=400) to (x=284,y=439)
MODIS surface
TM TOA
TM surface
% of area (1600 pixels)
Blue

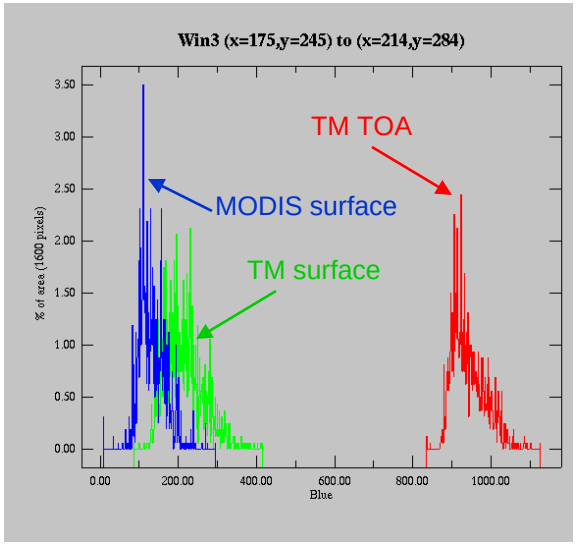

Win2 (x=245,y=400) to (x=284,y=439)
% of area (1600 pixels)
Green

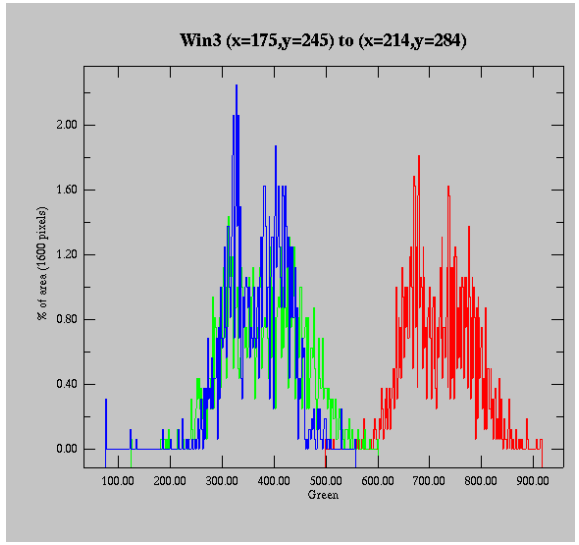

Win2 (x=245,y=400) to (x=284,y=439)
% of area (1600 pixels)
Red

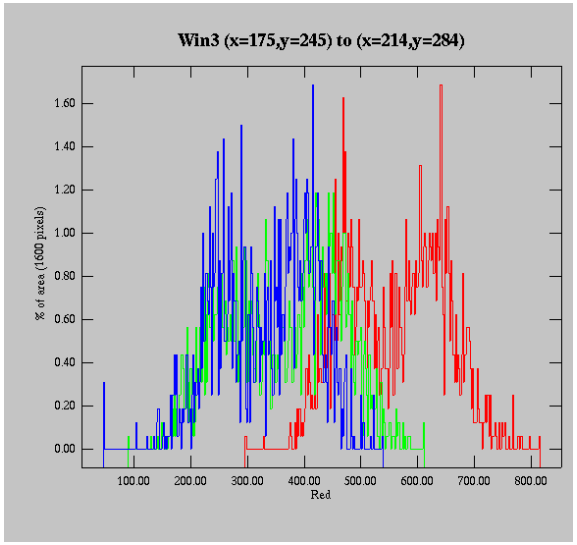

Win2 (x=245,y=400) to (x=284,y=439)
% of area (1600 pixels)
NIR

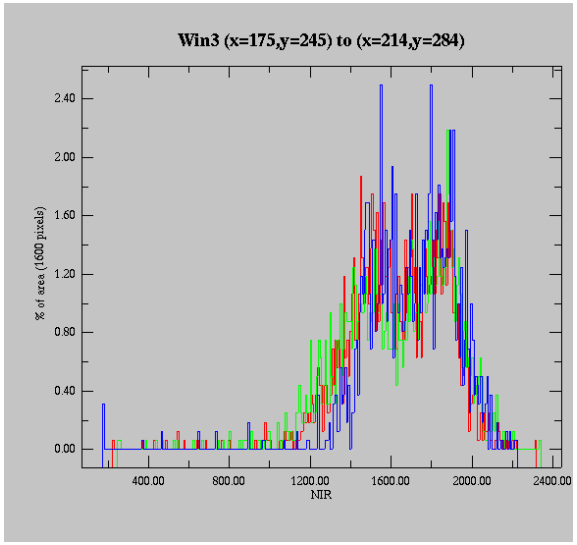

Win2 (x=245,y=400) to (x=284,y=439)
% of area (1600 pixels)
MIR

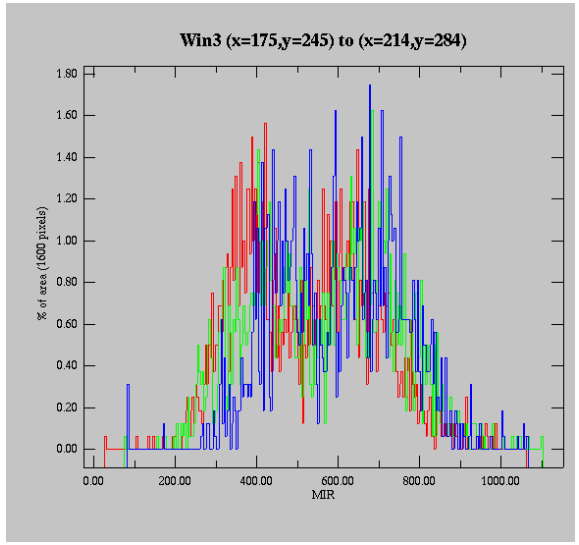
Window 3

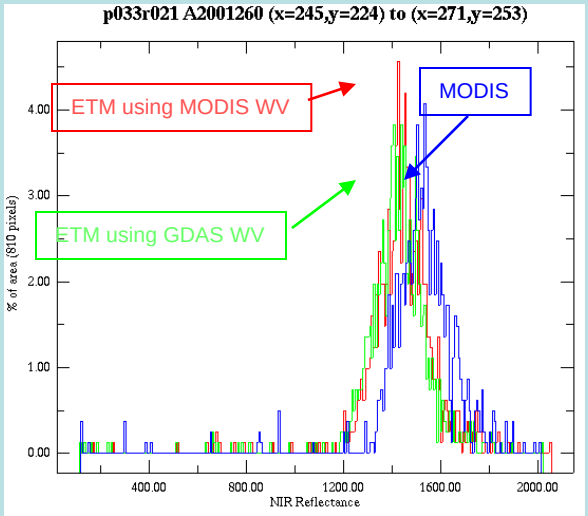

Win3 (x=175,y=245) to (x=214,y=284)
TM TOA
MODIS surface
TM surface
% of area (1600 pixels)
Blue

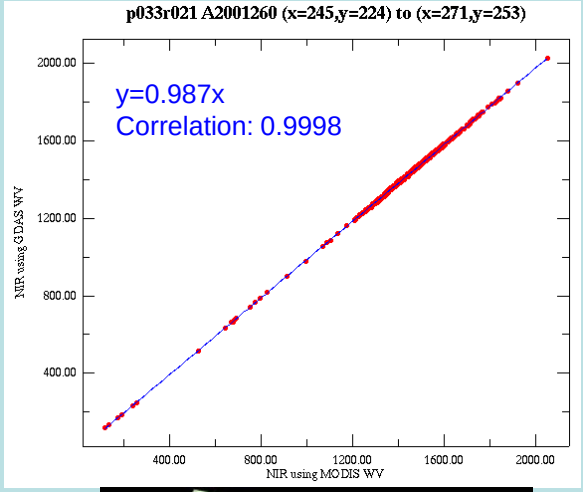

Win3 (x=175,y=245) to (x=214,y=284)
% of area (1600 pixels)
Green

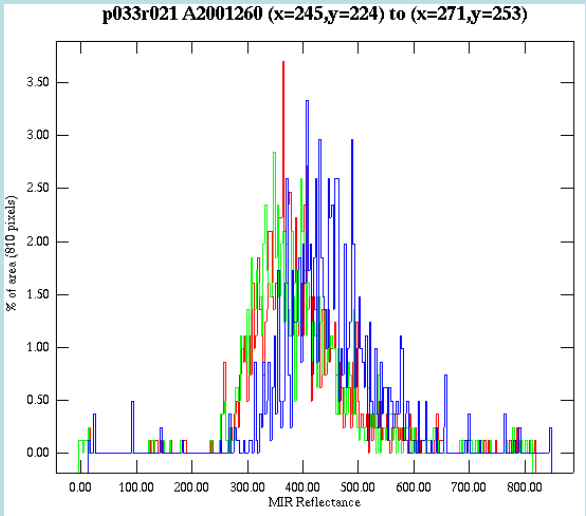

Win3 (x=175,y=245) to (x=214,y=284)
% of area (1600 pixels)
Red


Win3 (x=175,y=245) to (x=214,y=284)
% of area (1600 pixels)
NIR

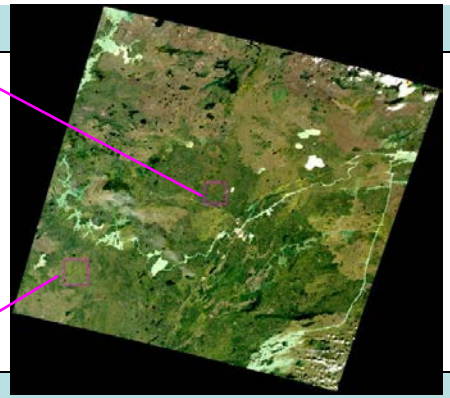

Win3 (x=175,y=245) to (x=214,y=284)
% of area (1600 pixels)
MIR



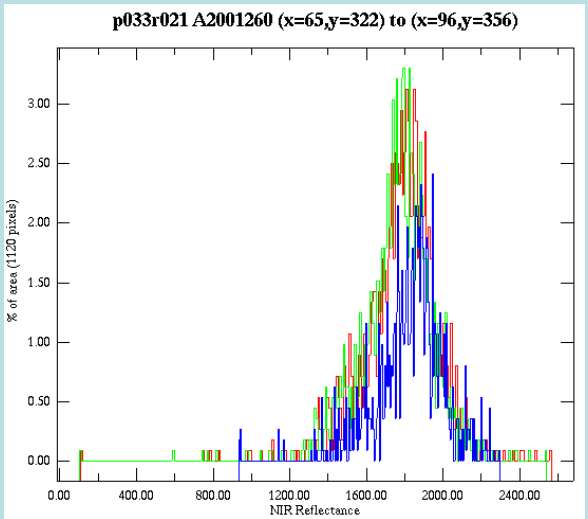


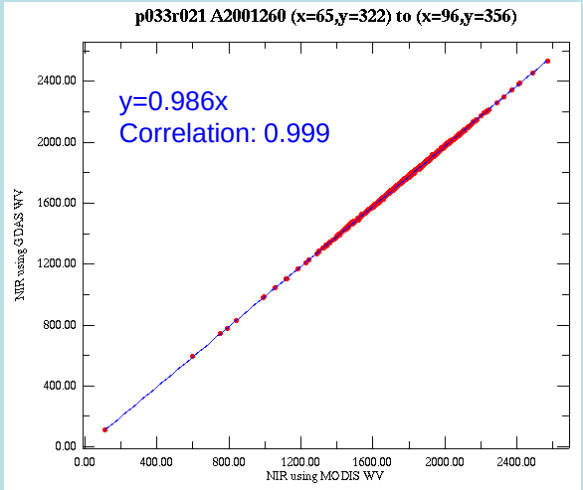


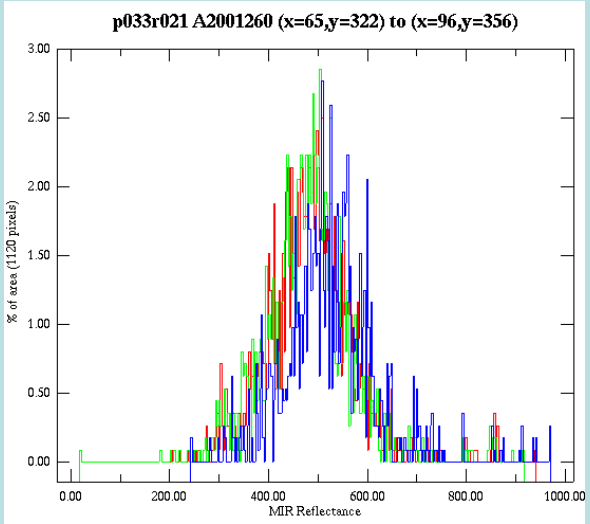
Scene : p033r021
Date: 17 Sep 2001
SZA: 55.45



Pressure = 1002.5 mbar
Ozone = 0.33 Dobson
GDAS WV = 0.92 g.cm^{-2}
MODIS WV = 1.3 g.cm^{-2}







Surface reflectance product from MODIS

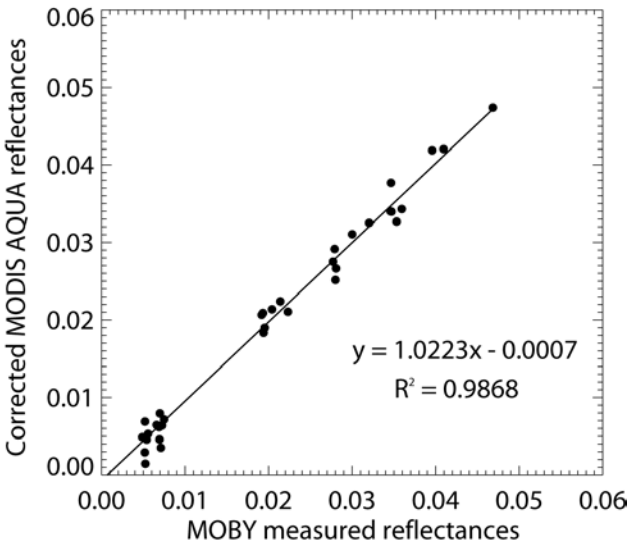
- The Surface Reflectance standard product developed for MODIS provides the basis for a number of higher order land products for global change and applications research

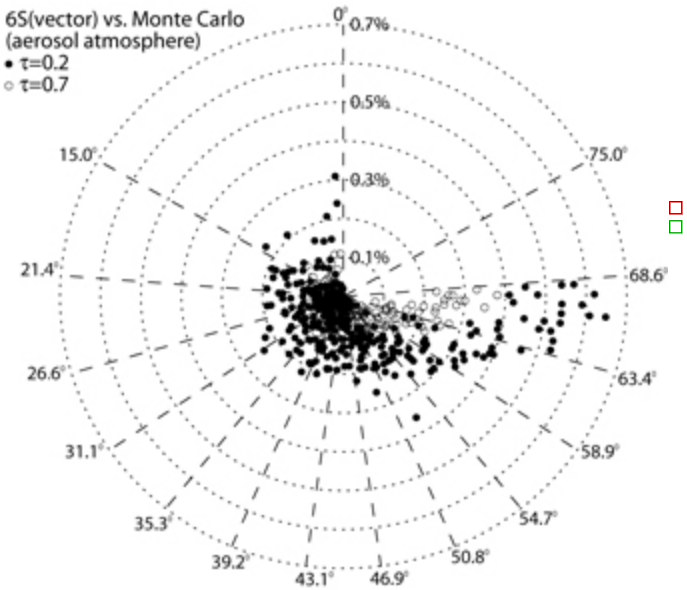
Approach for the surface reflectance product

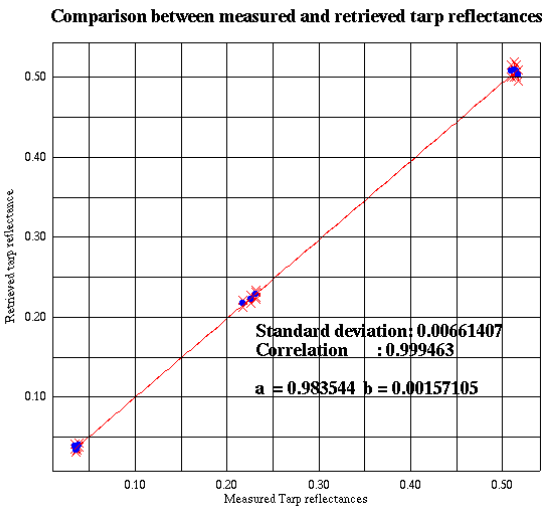
- **Atmospheric correction consistent with the MODIS, AVHRR and NPP-VIIRS approach, ensuring consistent reflectance data across resolutions based on rigorous radiative transfer**

  http://6s.ltdri.org

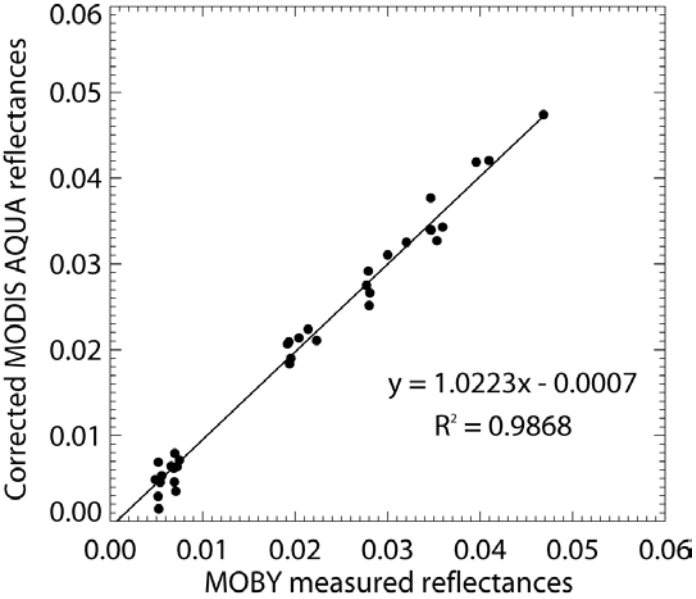
  http://rtcodes.ltdri.org/



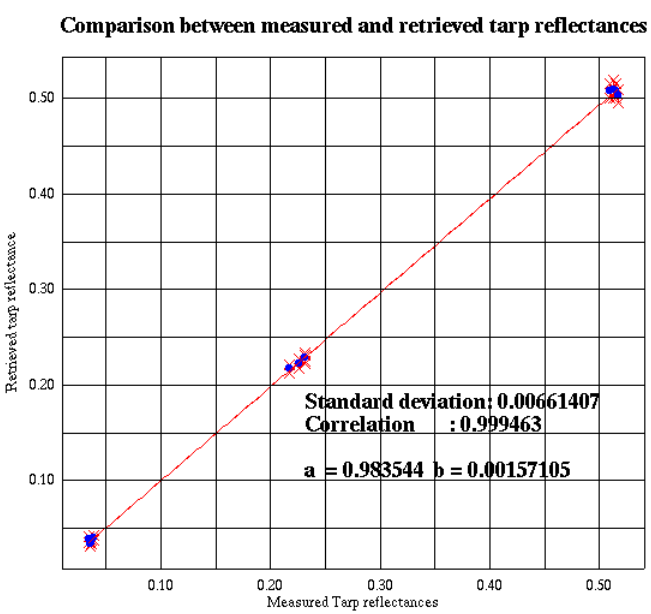




6SV Validation from ground measurements



The corrected MODIS AQUA water-leaving reflectances using AERONET and 6SV vs. the MOBY-measured water-leaving reflectances for λ = {412; 443; 490; 530; 550} nm. The MOBY data were collected off the coast of Lanai Island (Hawaii) during the year 2003 **(From Kotchenova et al., 2006).**



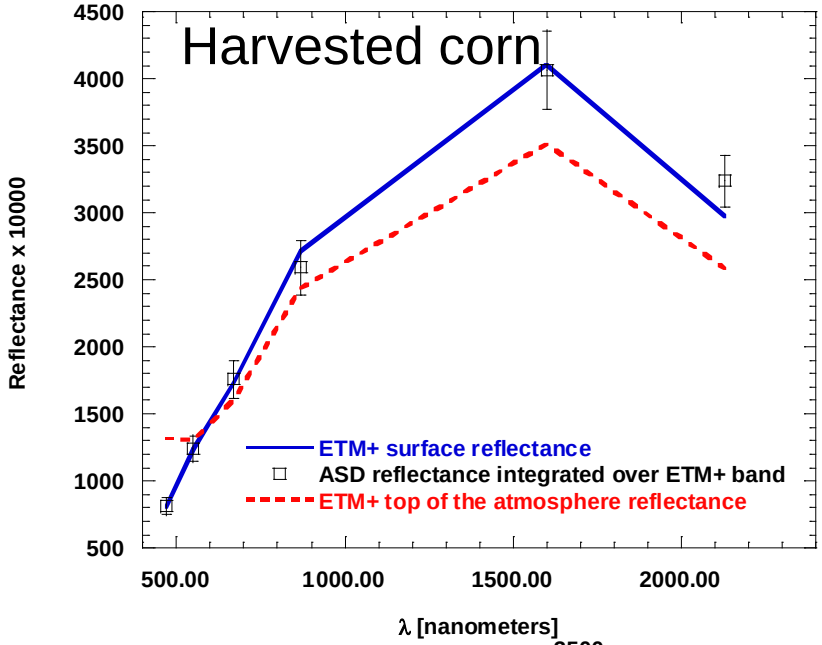
.The corrected IKONOS reflectance's using AERONET and 6SV (including adjacency effect correction) vs. the reference tarp reflectance's. The data were acquired over Stennis Space flight Center on February, 15, 2002**.**

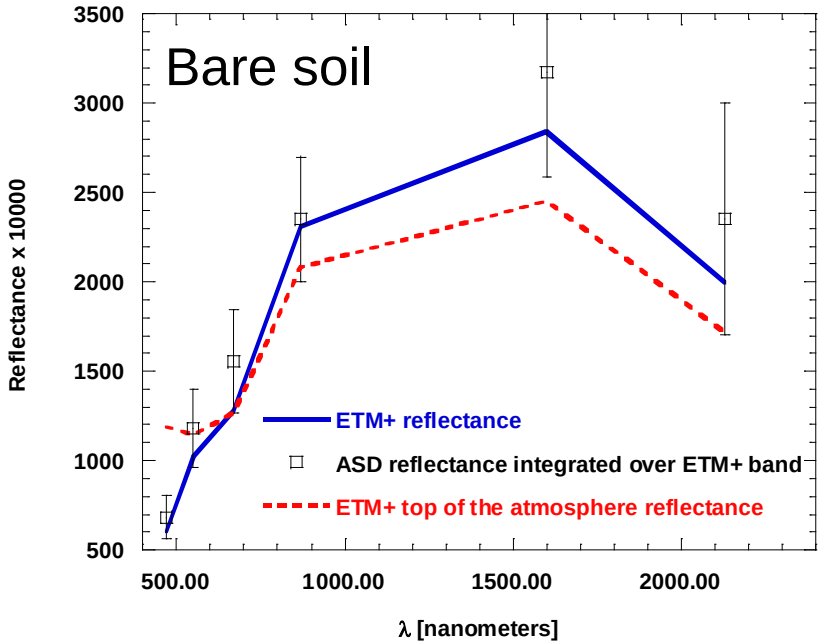
6S Radiative transfer code validation (Landsat)

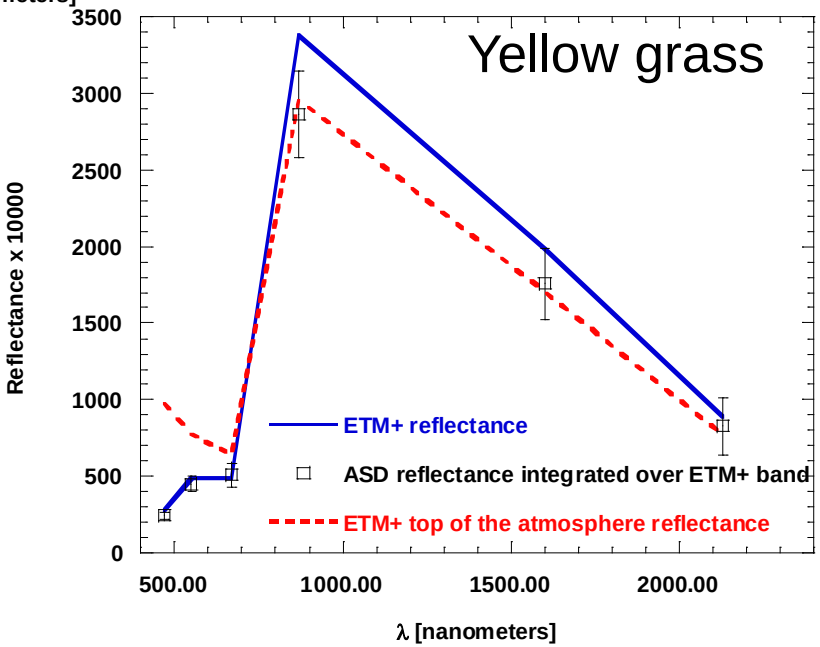
- Using AERONET sun photometer measurements, the atmospheric correction was performed over site where simultaneous measurements of the surface reflectance over selected sites (Bare soil, Harvested corn, Yellow grass) using a ASD spectrometer were performed.

- Despite strong heterogeneity of the sites showed by the measured standard deviation the agreement between the LANDSAT surface reflectance and the surface measurements is very good especially in the visible where the aerosol effect is the strongest.

6S Radiative transfer code validation (Landsat)

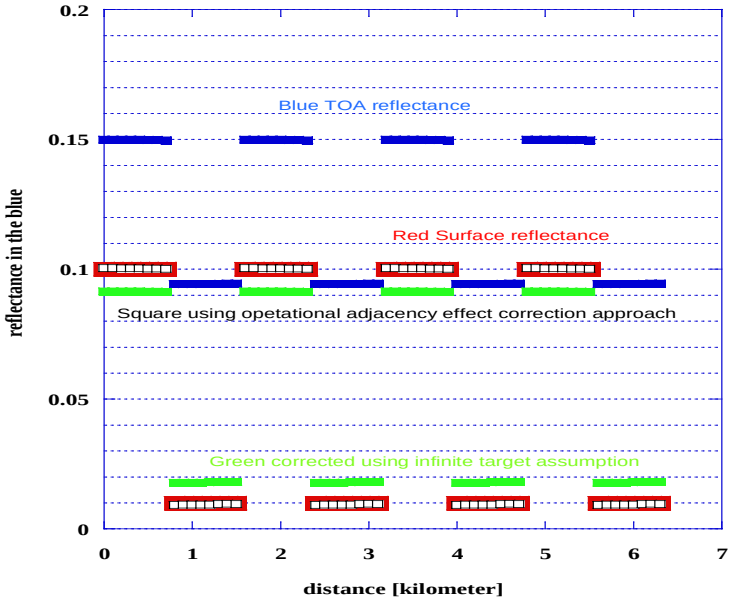


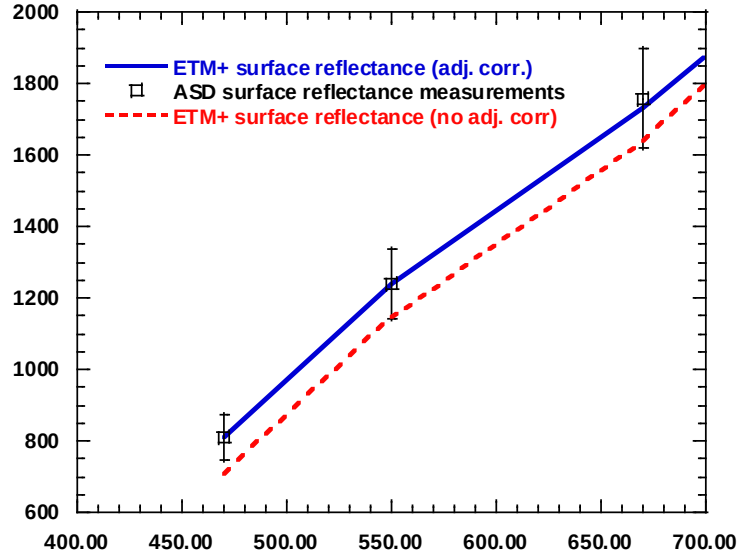




6S Radiative transfer code validation (Landsat)

- Using the Harvested corn site (bright surrounded by dark forest) we were able to show that the adjacency effect correction tested theoretically was improved the agreement between measurement and Landsat surface reflectance





Theoretical uncertainties for thr surface reflectance MODIS product

- **Validation and uncertainties estimates. Theoretical error budget, comprehensive evaluation.**

FOREST

Belterra

λ [nm]	ρ x10000	Clear	Average	Hazy
			Δρx10000	
470	120	52	51	52
550	375	49	55	64
645	240	52	59	65
870	2931	40	152	246
1240	3083	38	110	179
1650	1591	29	52	84
2130	480	41	28	42
NDVIx1000			ΔNDVI x1000	
849		30	34	40

SAVANNA

Skukuza

λ [nm]	ρ x10000	Clear	Average	Hazy
			Δρx10000	
470	400	52	52	53
550	636	52	58	64
645	800	53	62	67
870	2226	35	103	164
1240	2880	38	97	158
1650	2483	35	66	104
2130	1600	40	36	53
NDVIx1000			ΔNDVI x1000	
471		22	28	33

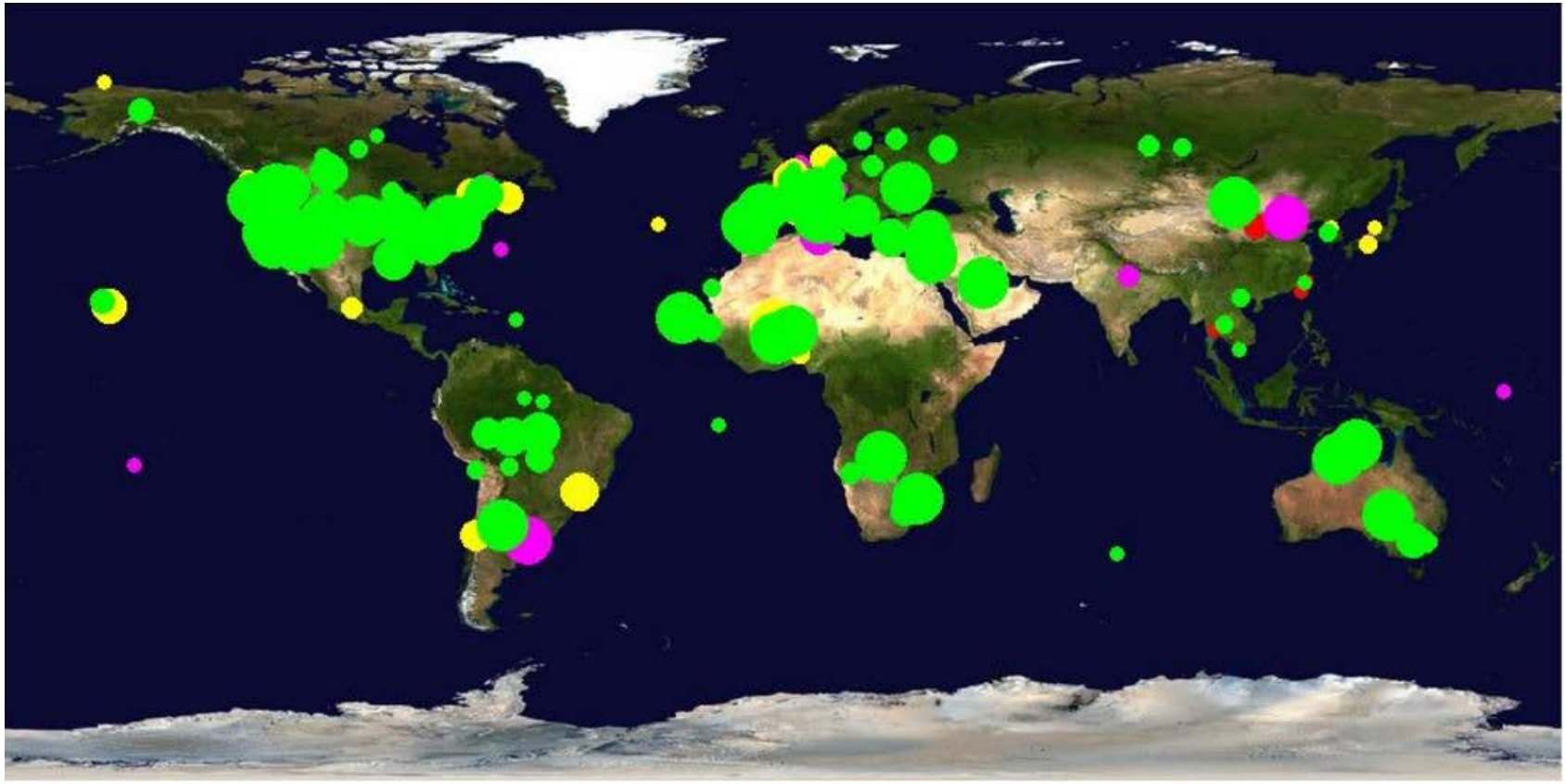
SEMI-ARID

Sevilleta

λ [nm]	ρ x10000	Clear	Average	Hazy
			Δρx10000	
470	700	51	53	55
550	1246	51	70	85
645	1400	57	74	85
870	2324	41	95	146
1240	2929	45	93	148
1650	3085	55	81	125
2130	2800	56	60	87
NDVIx1000			ΔNDVI x1000	
248		11	15	19

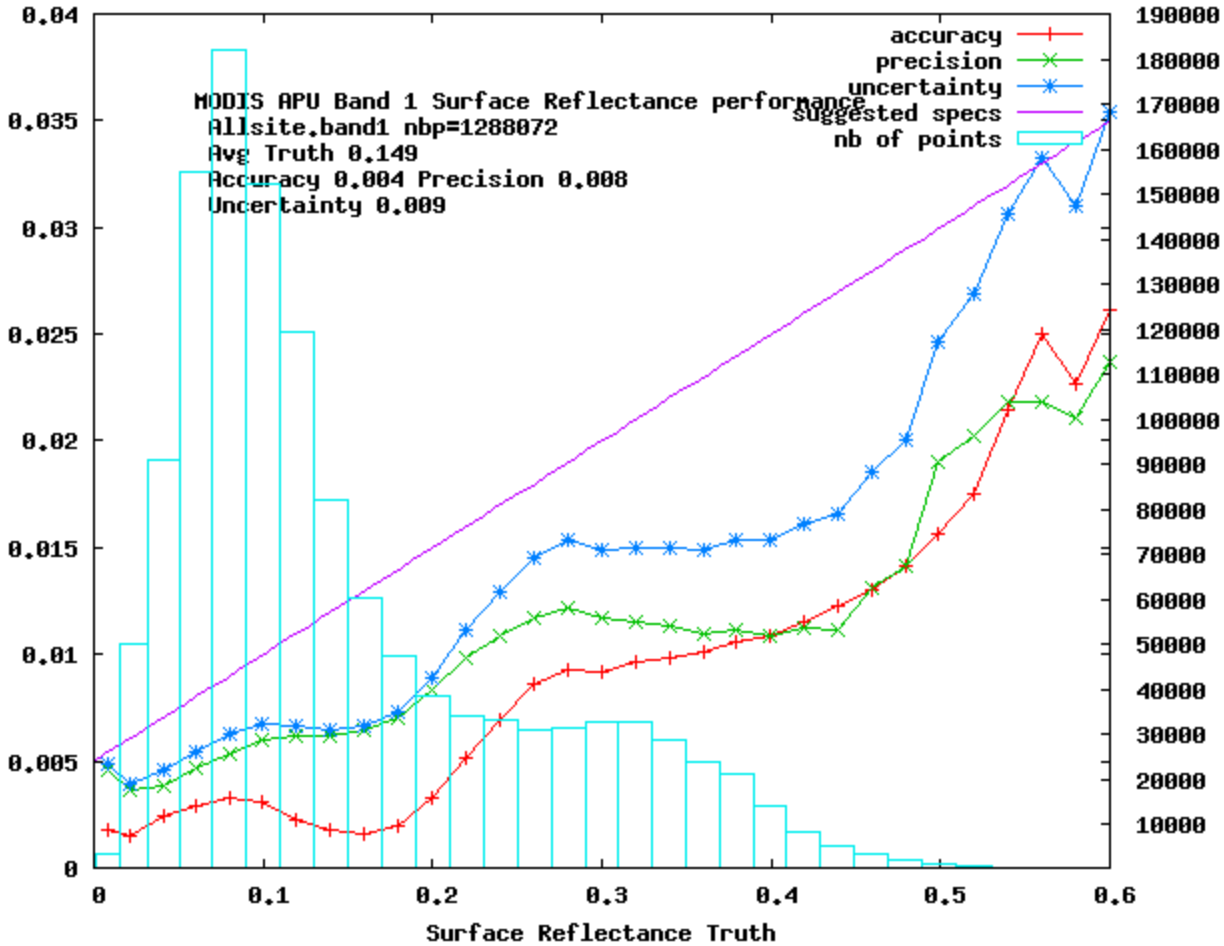
Error in ~0.5% in reflectance unit

Comprehensive analysis of performance using the AERONET network 2000-2007 Results (25542 cases)



Version 2 AERONET (i.e. with Background correction and spheroid)

Toward a quantitative assessment of performances (APU)



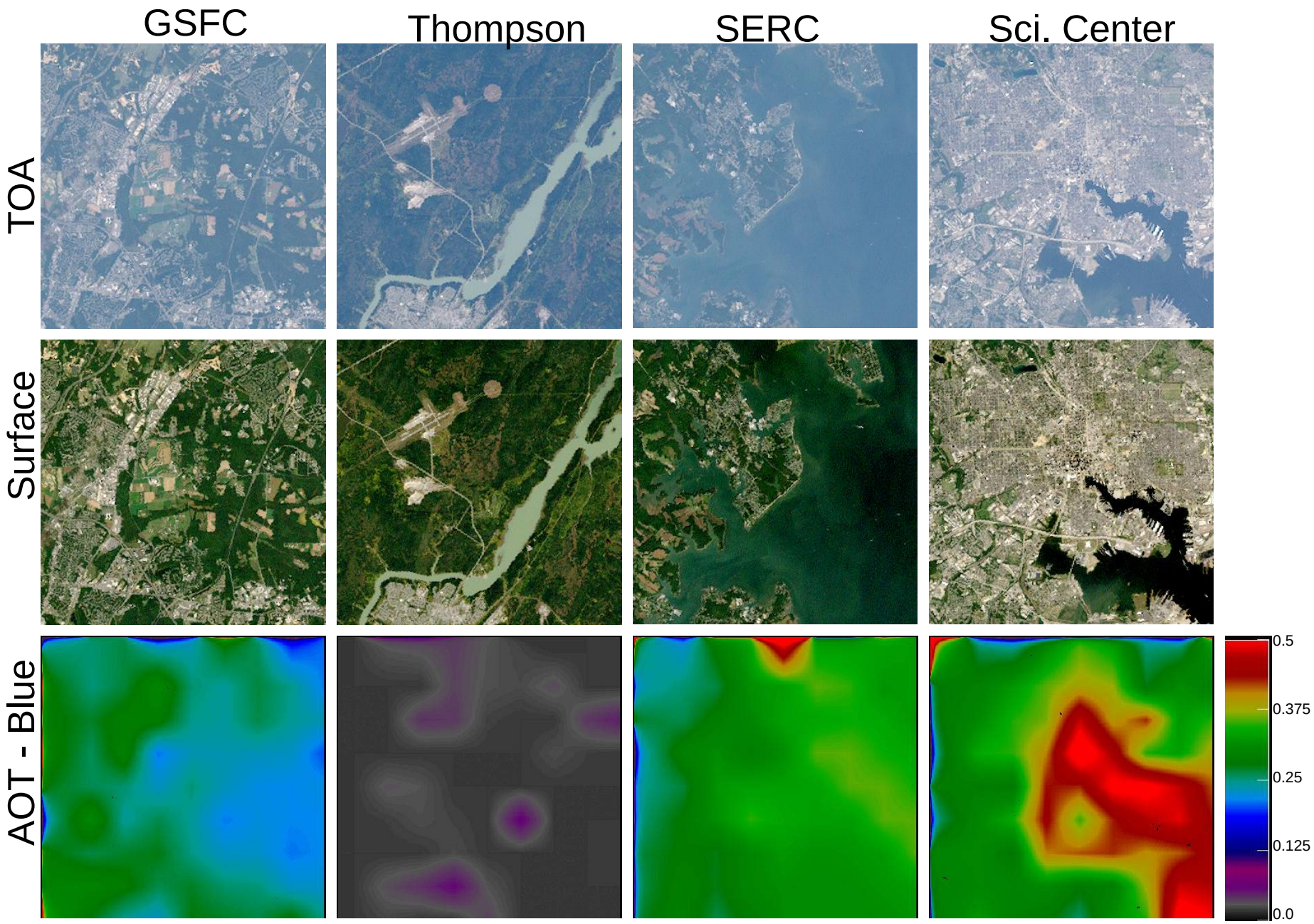
1,3 Millions 1 km pixels were analyzed for each band.

Red = Accuracy (mean bias)
Green = Precision (repeatability)
Blue = Uncertainty (quadatric sum of A and P)

On average well below magenta theoretical error bar

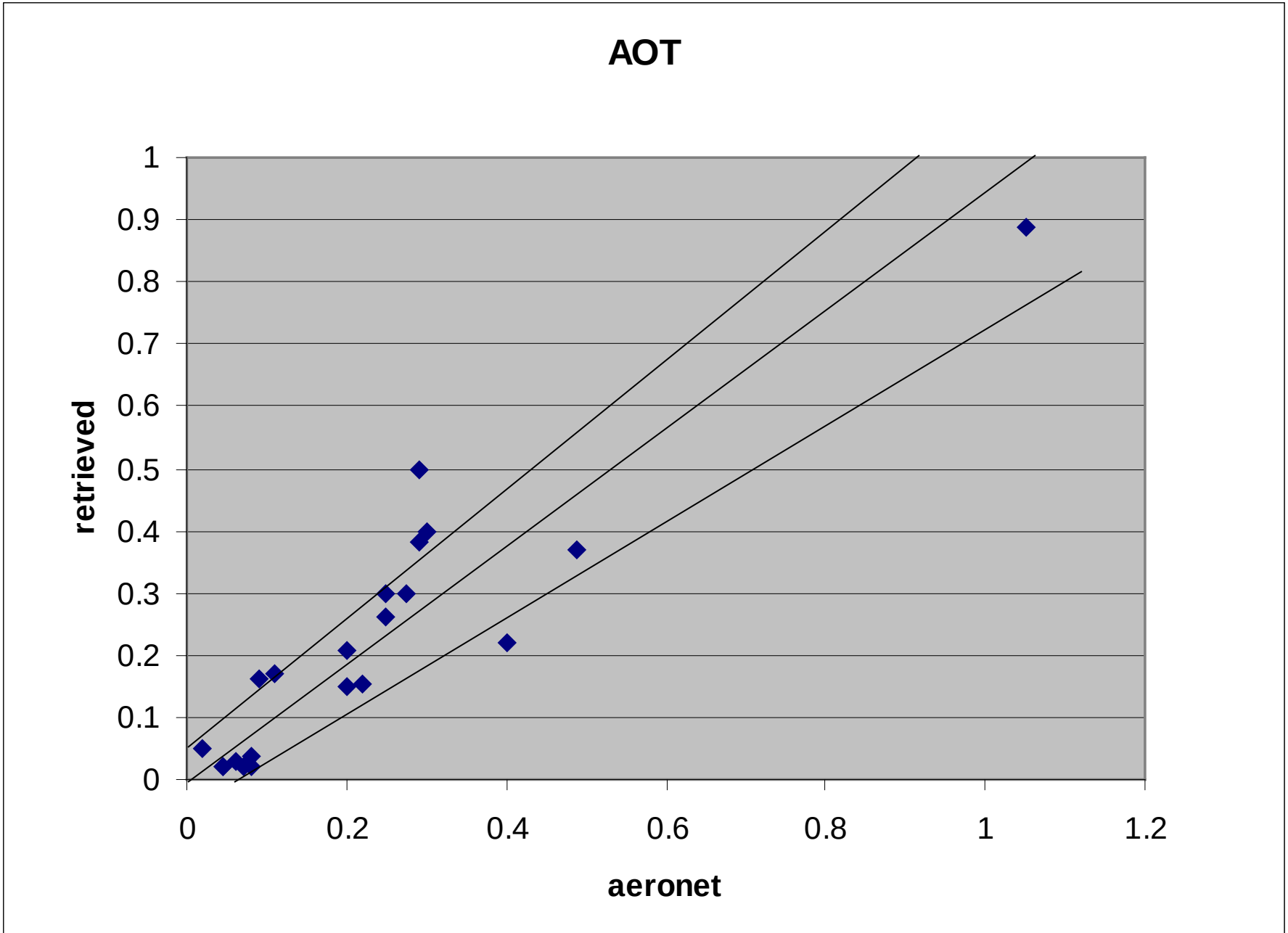
Evaluation of the improved method for Landsat atmospheric correction

- The retrieval of the aerosol optical depth is performed at 1km resolution (as MODIS)
- A subset of scene (urban, coastal, forest, urban-coastal) was chosen to evaluate the performance of the correction and retrieval
- The performance of the correction was assessed by comparing for these subsets the retrieved versus measured (AERONET) optical depth.

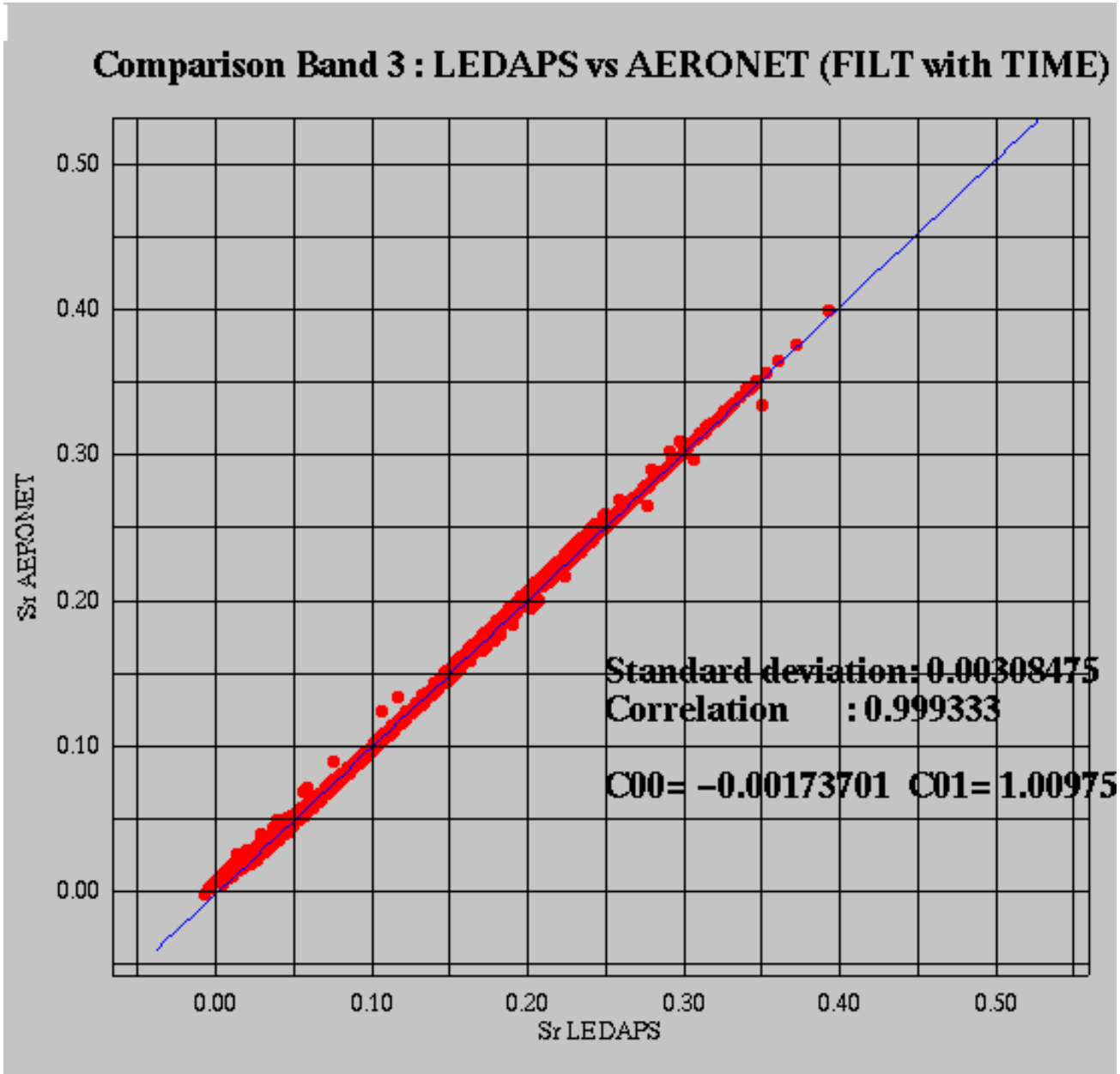

GSFC
Thompson
SERC
Sci. Center
TOA
Surface
AOT - Blue
0.5
0.375
0.25
0.125
0.0

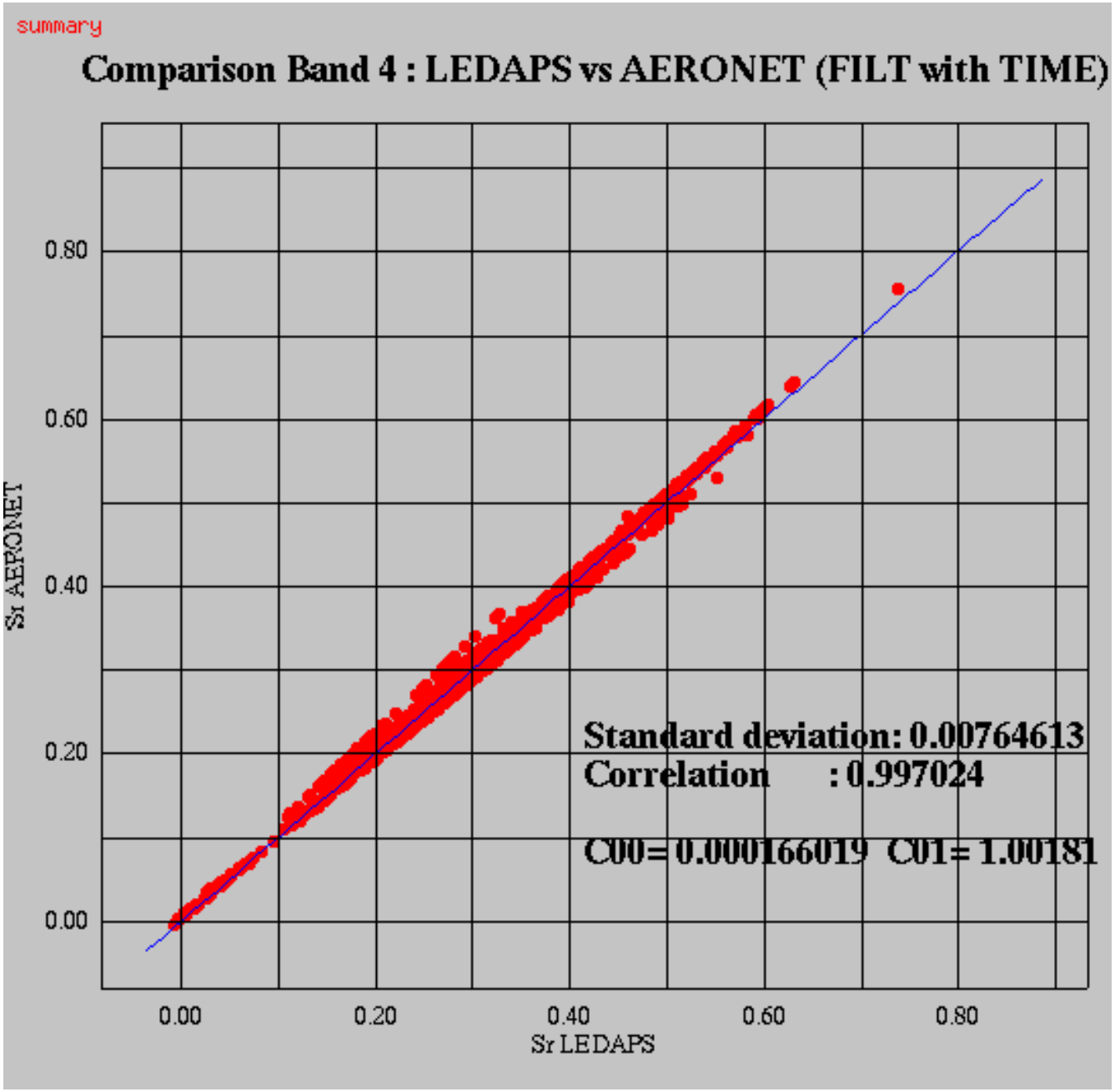
Measured & Retrieved AOT

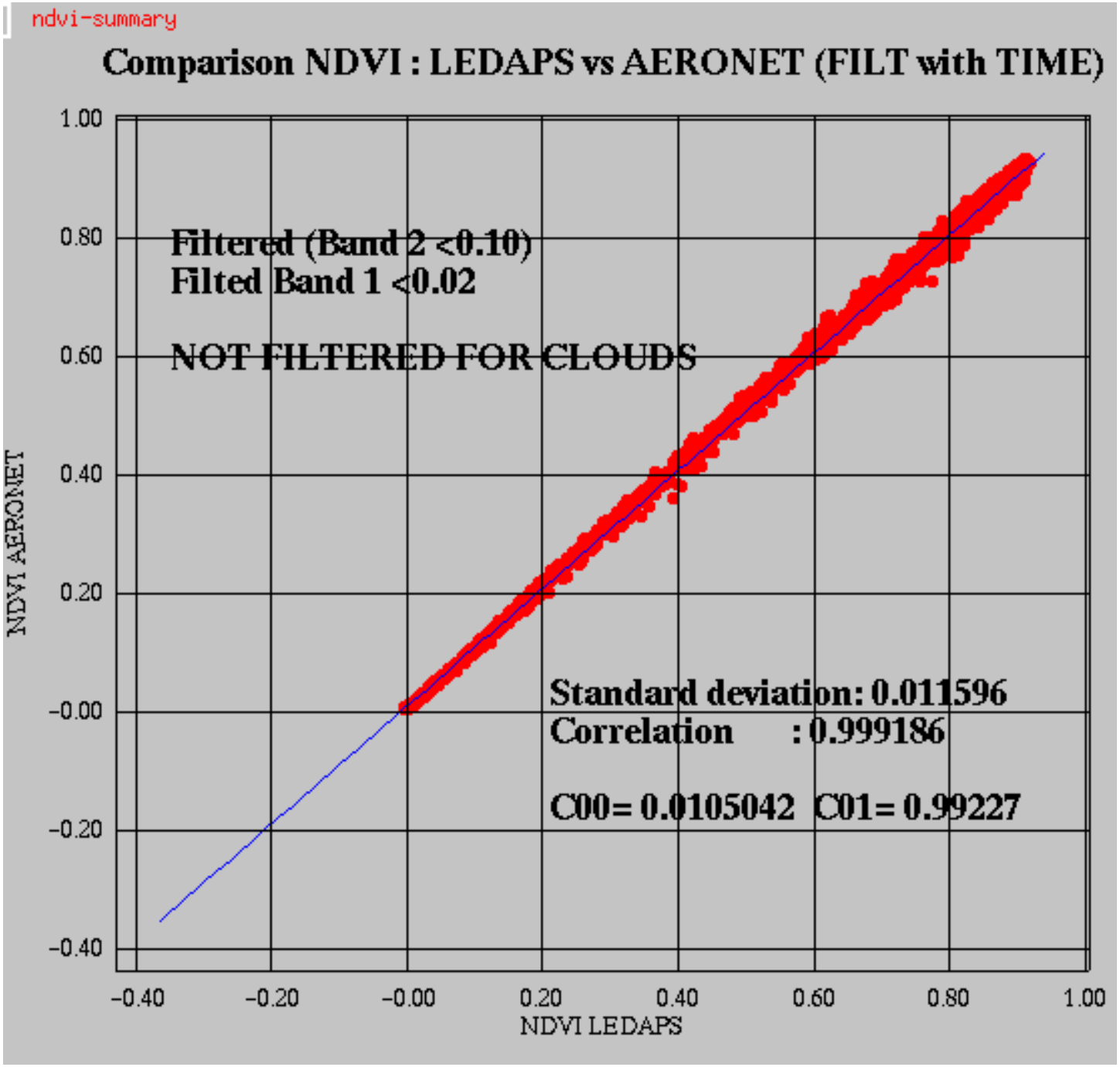
Site	Date	TM scene	Aeronet	ETM
GSFC	20011005	p015r033	.25	.26
MD Science Center	20011005	p015r033	.29	.5
SERC	20011005	p015r033	.25	.3
Thompson	20010917	p033r021	.06	.03
Waskesiu	20010812	p037r022	.044	.02
Waskesiu	20010812	p037r023	.044	.02
HJAndrews	19991002	p045r029	.08	.038


AOT
retrieved
aeronet
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1
1.2

Landsat Surface reflectance validation



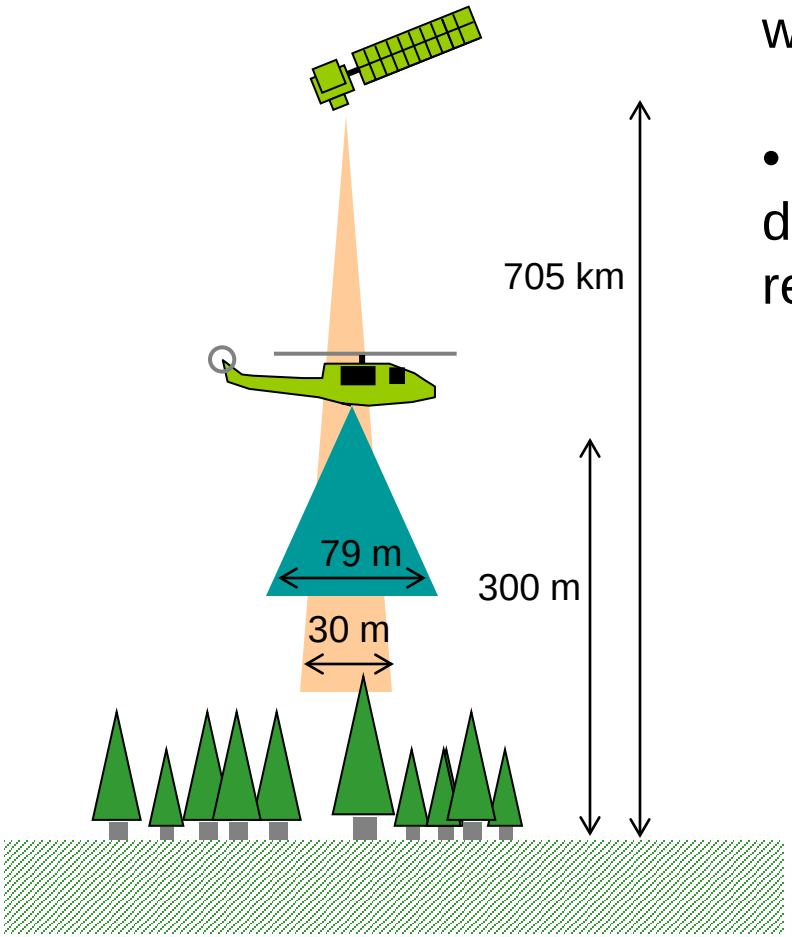

summary
Comparison Band 4 : LEDAPS vs AERONET (FILT with TIME)
Sr AERONET
0.00
0.20
0.40
0.60
0.80
Sr LEDAPS
0.00
0.20
0.40
0.60
0.80
Standard deviation: 0.00764613
Correlation : 0.997024
C00= 0.000166019 C01= 1.00181


ndvi-summary
Comparison NDVI : LEDAPS vs AERONET (FILT with TIME)
Filtered (Band 2 <0.10)
Filted Band 1 <0.02
NOT FILTERED FOR CLOUDS
Standard deviation: 0.011596
Correlation : 0.999186
C00= 0.0105042 C01= 0.99227
NDVI AERONET
NDVI LEDAPS
1.00
0.80
0.60
0.40
0.20
-0.00
-0.20
-0.40
-0.40
-0.20
-0.00
0.20
0.40
0.60
0.80
1.00

Validation activities status (cont.)

- Preliminary validation has been done by comparison to ground surface measurements (ASD) and Helicopter based measurements (MMR)

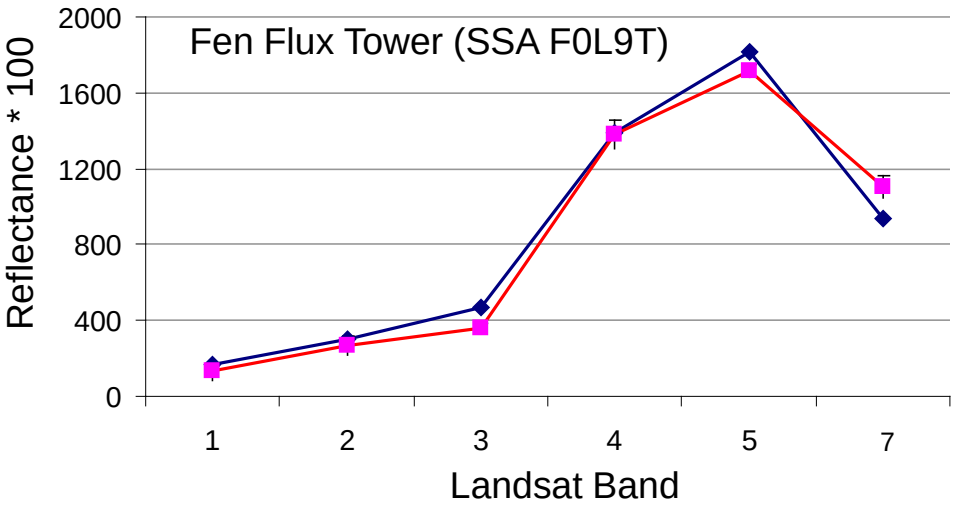
BOREAS Barnes MMR Data

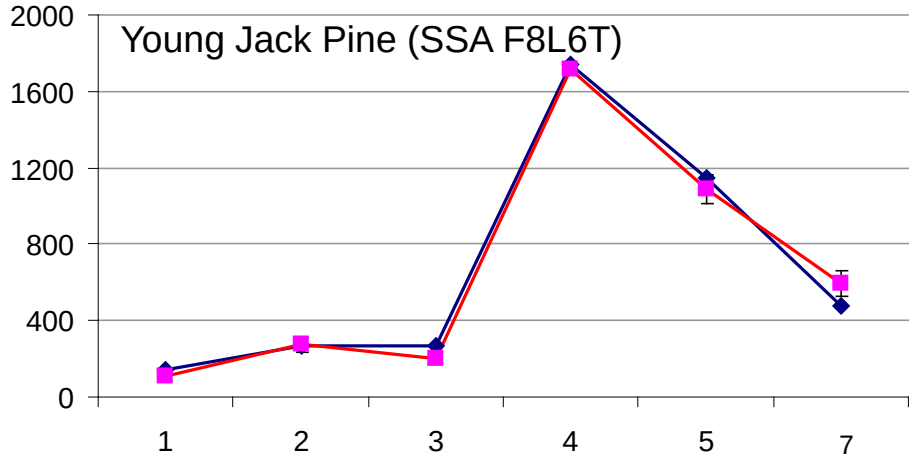


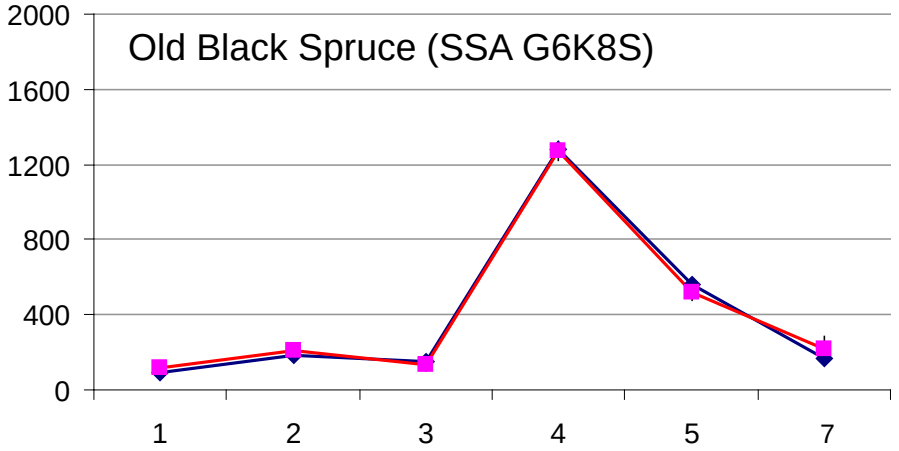
- BOREAS flew Barnes MMR (Modular Multiband Radiometer) on helicopter, with sun photometer, in 1994

- Processing of simultaneous Landsat-5 data (+/- 5 days) allows validation of reflectance algorithm

MMR vs. Landsat Reflectance: SSA





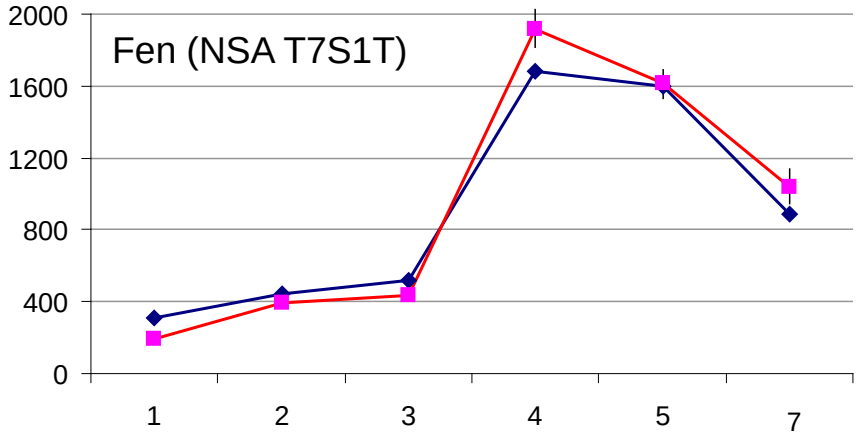


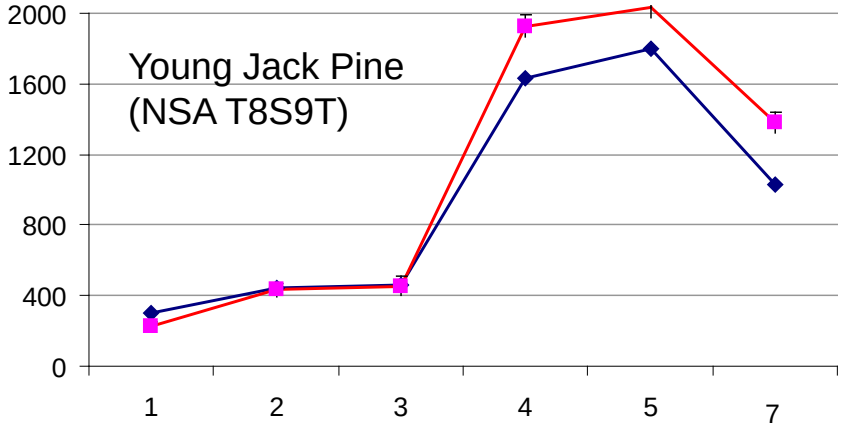
Helicopter MMR data (9/16/94)

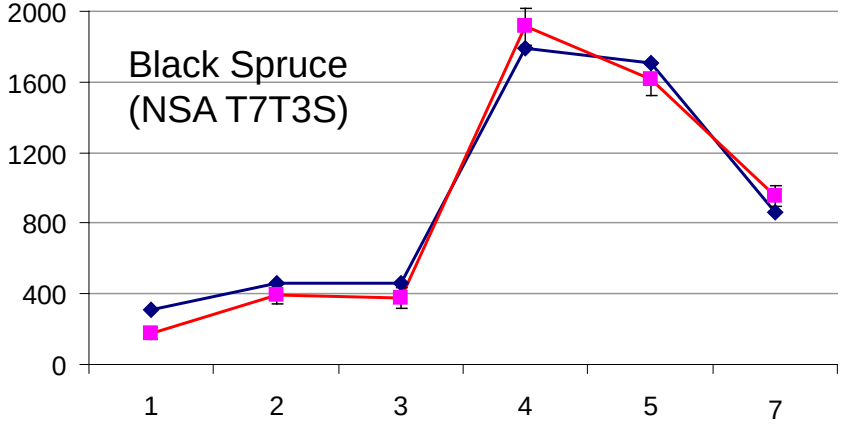
Landsat-5 TM Reflect. (9/18/94)

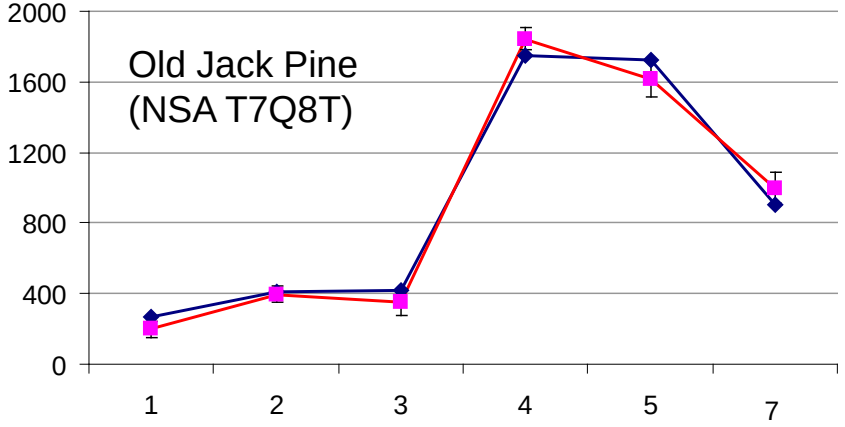
Error bars = +/- 1 std dev within 3x3 pixel window of center

MMR vs. Landsat Reflectance: NSA





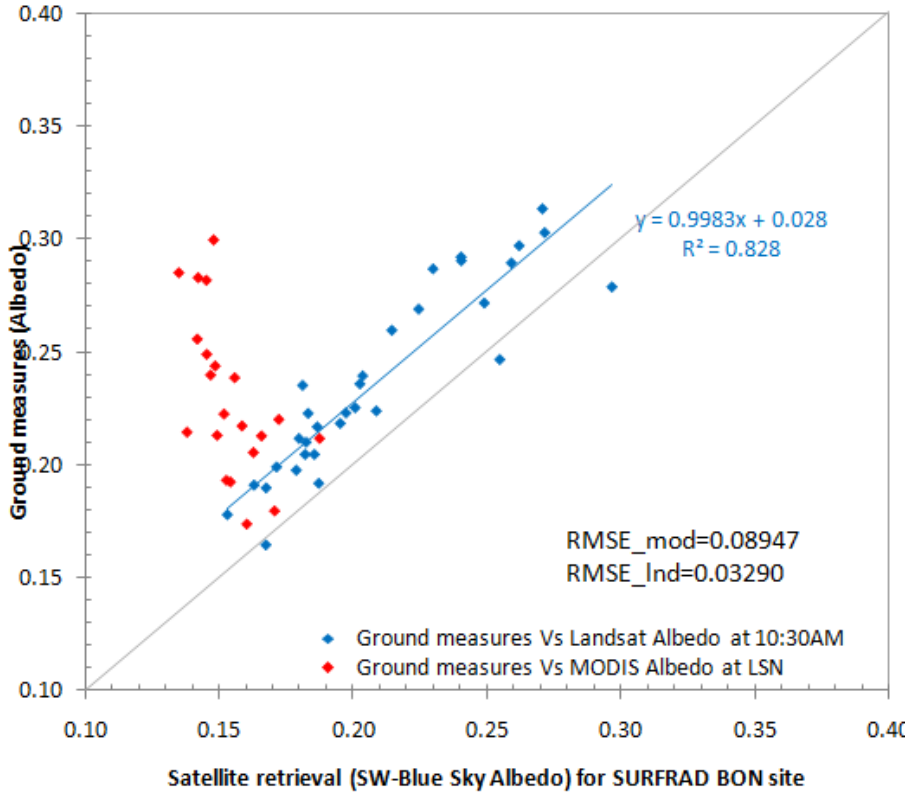




On going assessment of LEDAPS ETM+ surface reflectance product

- WELD (D. Roy) 120 acquisitions over 23 AERONET sites (CONUS) –in Review
- Google Earth Engine : Acquisitions over 120 AERONET sites (global) – In progress going for 300
- GFCC: Comparison with MODIS SR products
  - GLS 2000 demonstration (in press)
  - GLS 2005 (TM and ETM+) – In progress

Landsat/LDCM spatial resolution offer better validation opportunity

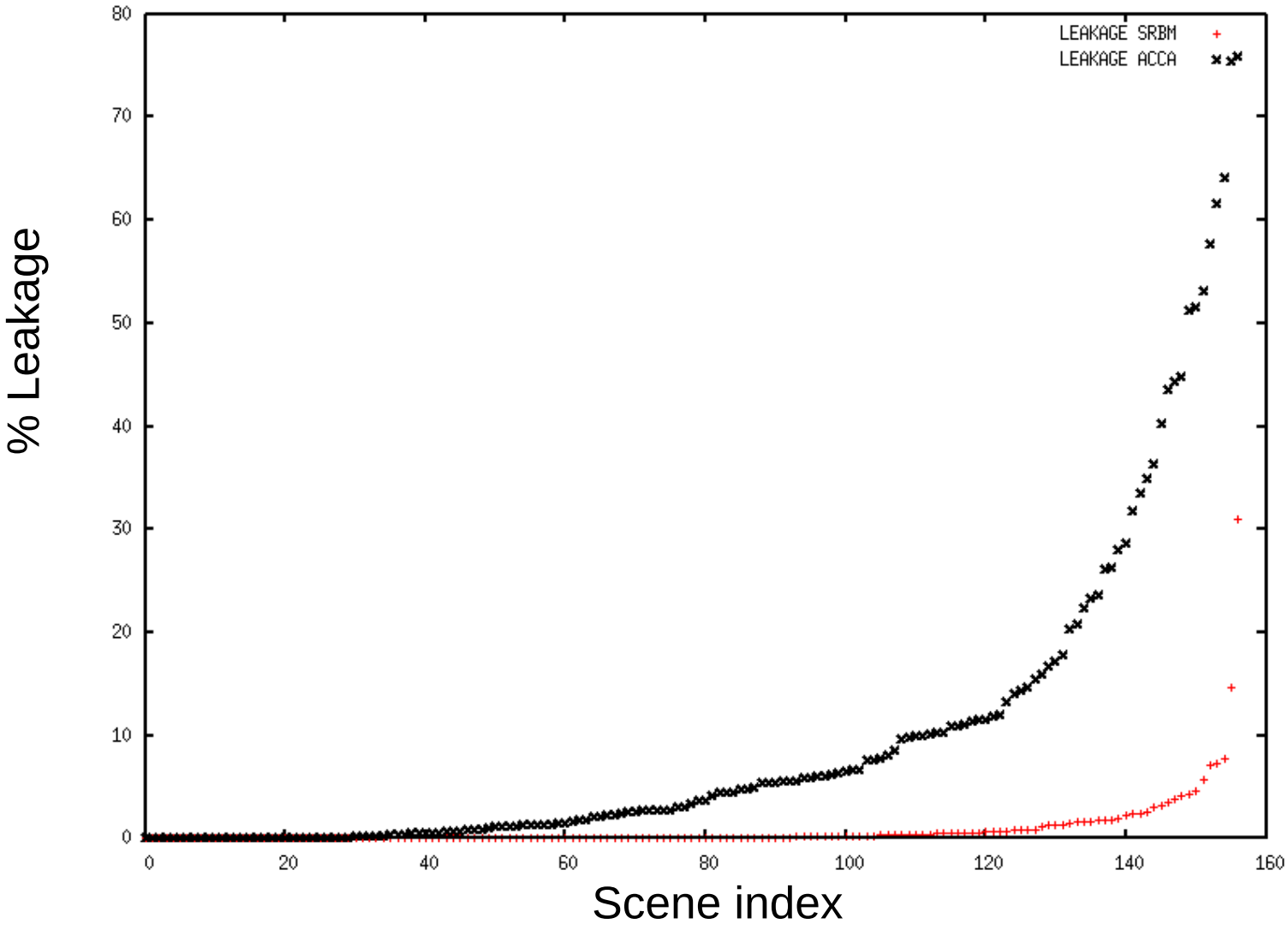


Courtesy of Feng Gao

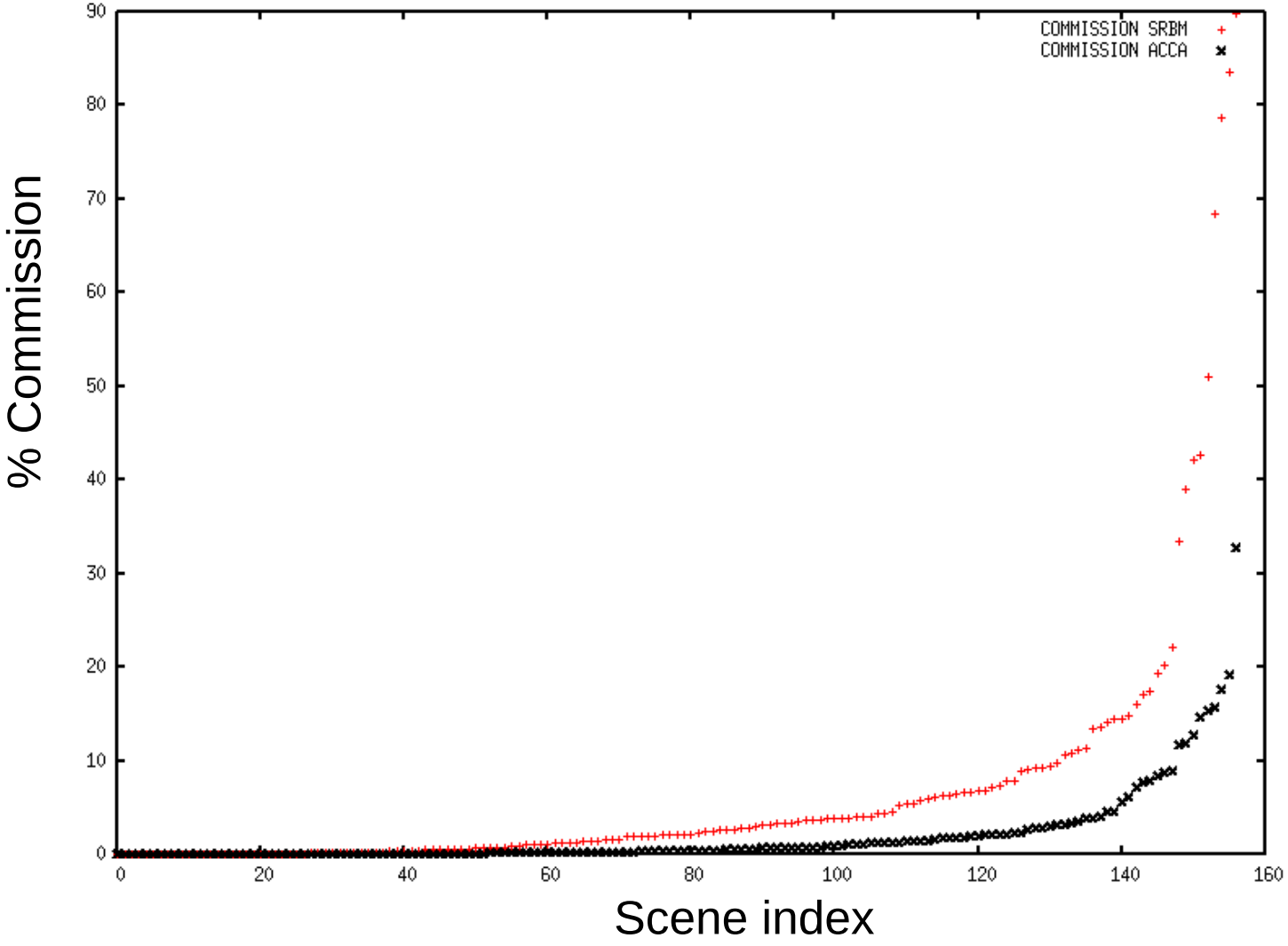
The Internal cloud/cloud shadow mask

- Performed in two stages (TOA first / SR second stage)
- Evaluated for 157 Landsat scenes covering a variety of conditions
- Cloud mask comparison
  - ACCA cloud mask
  - SRBM (Surface reflectance Based Mask): Internal cloud mask based on SR product
  - VCM :Truth Validation Cloud Mask (operator made)
- Metrics for cloud detection versus VCM
  - Rate of omission of cloud %: Leakage
  - Rate of commission of cloud % : False detection
- As far as leakage the internal cloud mask, SRBM, is superior to ACCA/ In term of commission ACCA has better performance than SRBM
- SRBM performance were confirmed bythe comparison with Zhe et al. Cloud Mask over 143 scenes.
- LEDAPS SRB shadow algorithm needs improvements

LEAKAGE RATE comparison



COMMISSION RATE Comparison



Sentinel 2 and TerEDyn

- Have similar spectral bands than LDCM/Landsat enabling the last version of aerosol retrieval and surface reflectance to be implemented
- Validation protocols are well defined and could be implemented
- Inter-comparison of products should be looked before launch (near coincidence, spectral differences etc…)

Conclusions

- Surface reflectance algorithm is mature and pathway toward validation and automated QA is clearly identified.
- Algorithm is generic and tied to documented validated radiative transfer code enabling easier inter-comparison and fusion of products from different sensors (MODIS,VIIRS,AVHRR, LDCM, Landsat, Sentinel 2 …)