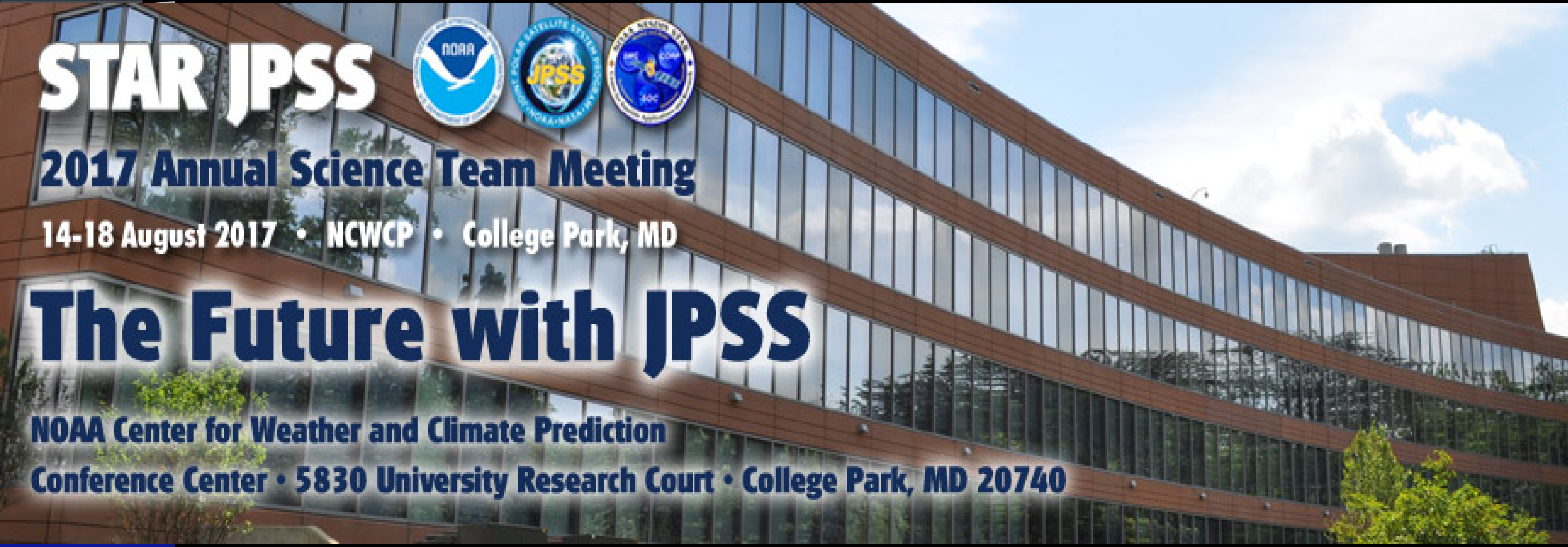
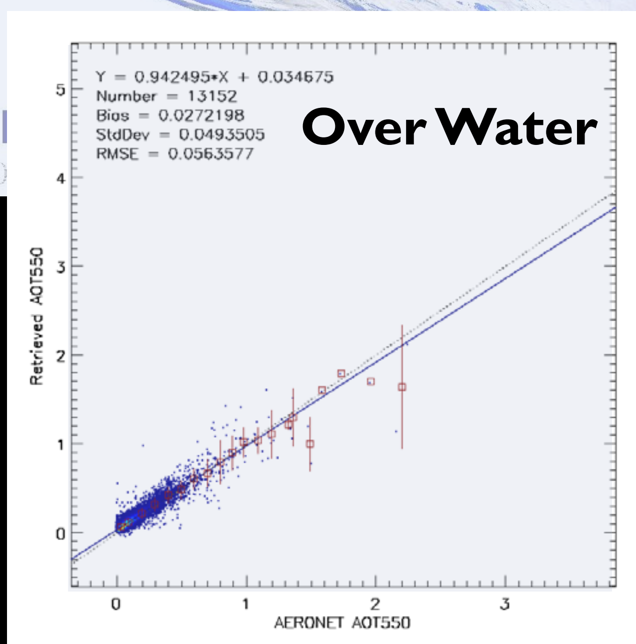


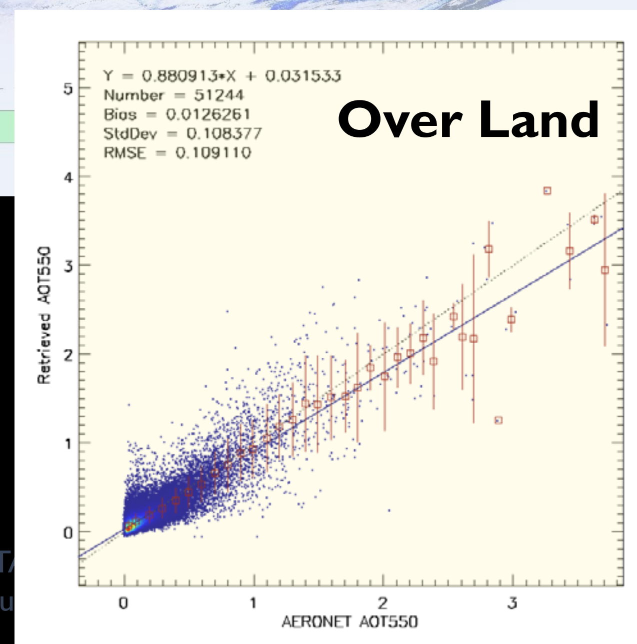
Evaluation of the VIIRS Enterprise Processing System AOD using AERONET over Different Geographic Regions

Hongqing Liu
and NOAA STAR Aerosol Cal/Val Team

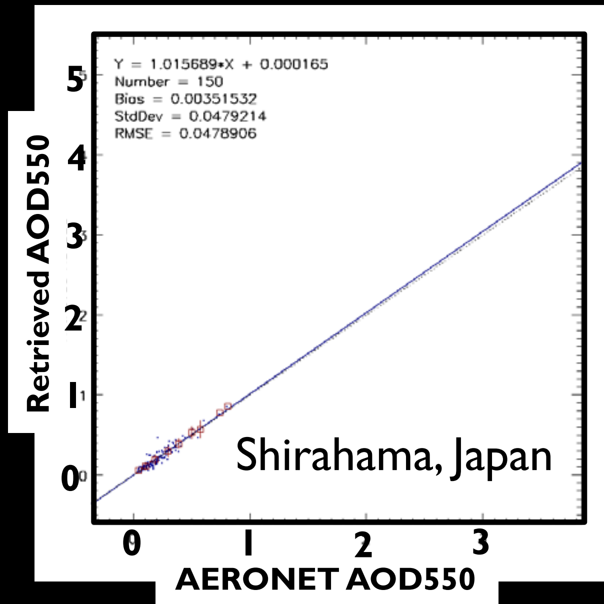
EPS AOD Algorithm

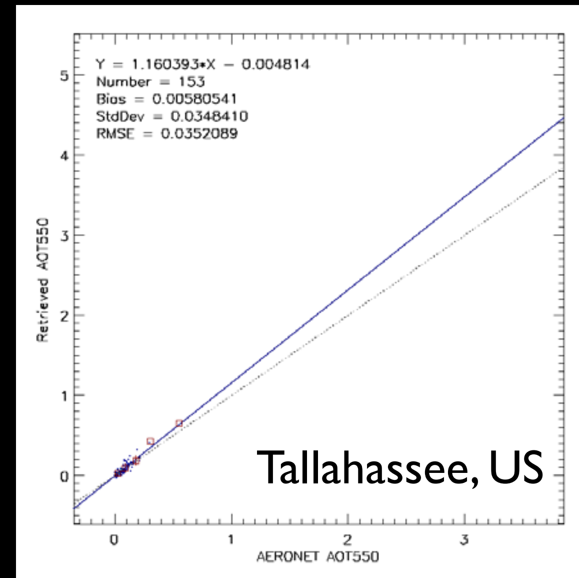
- **Multi-spectral aerosol retrieval**
- **Applied to VIIRS and ABI/AHI at pixel level**
- **Retrieval Coverage**
  - **Daytime cloud and snow/ice-free areas**
  - **Land: dark and bright**
  - **Ocean: non-glint deep water**
  - **AOD at 0.55μm: from -0.05 to 5.0**
- **High-quality retrievals meet requirement**
  - **Larger RMSE over land**

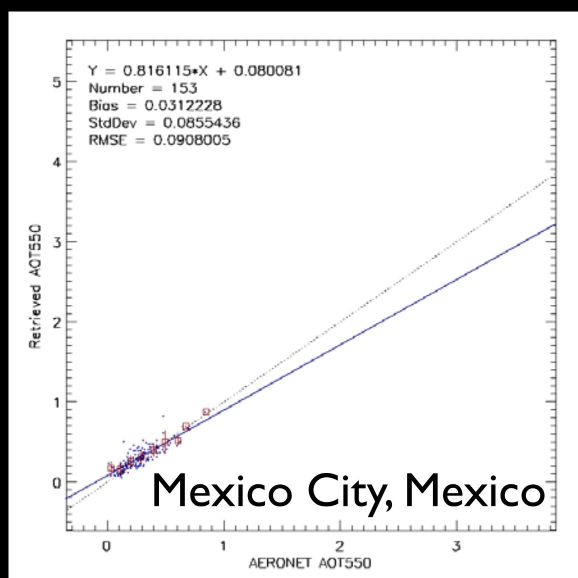


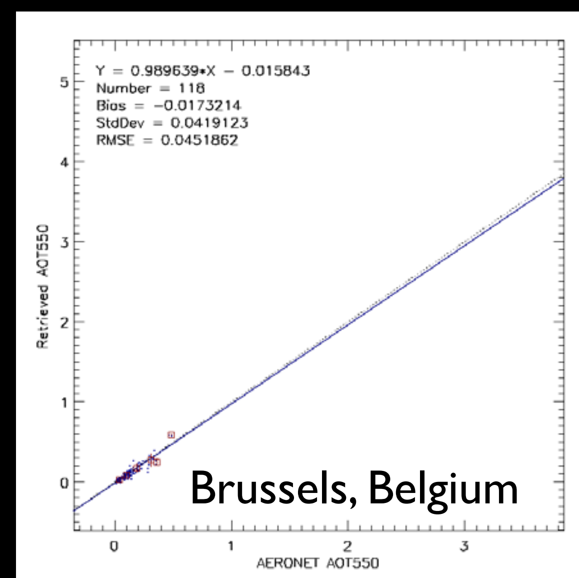


Example of Accurate Regional Retrievals

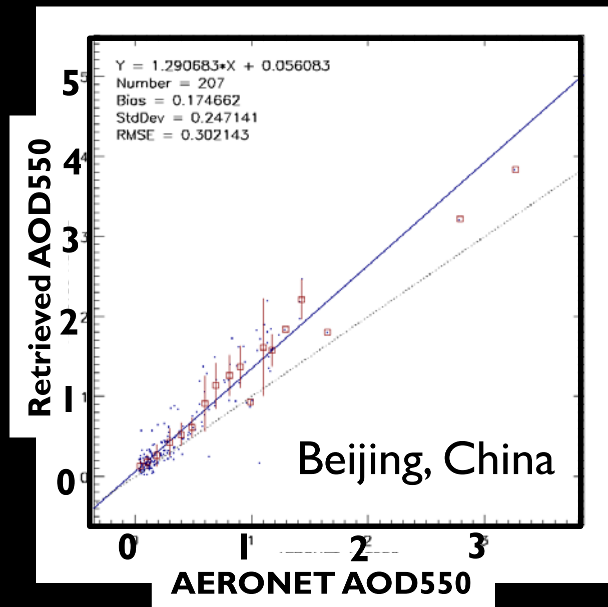


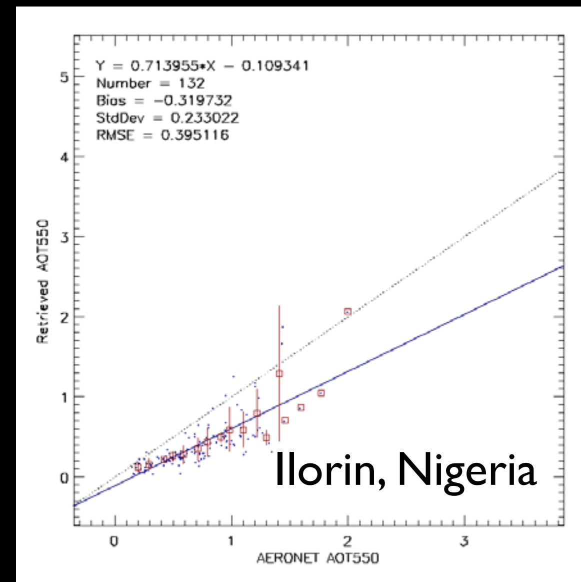


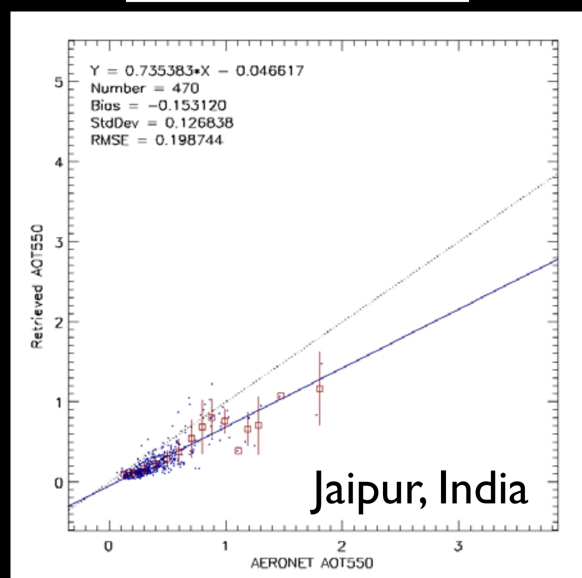


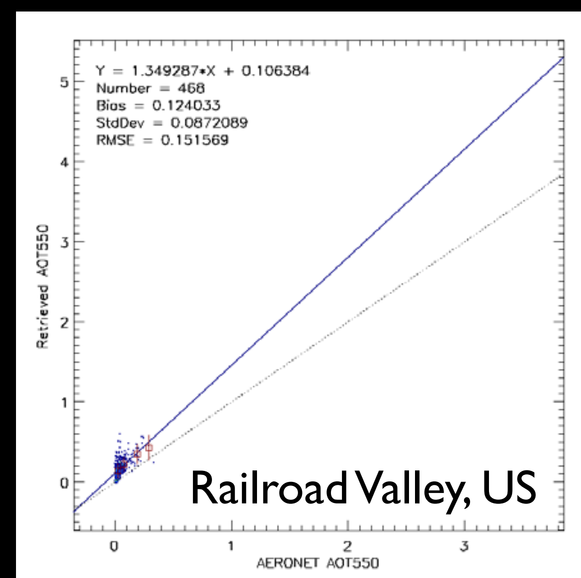


Example of Biased Regional Retrievals



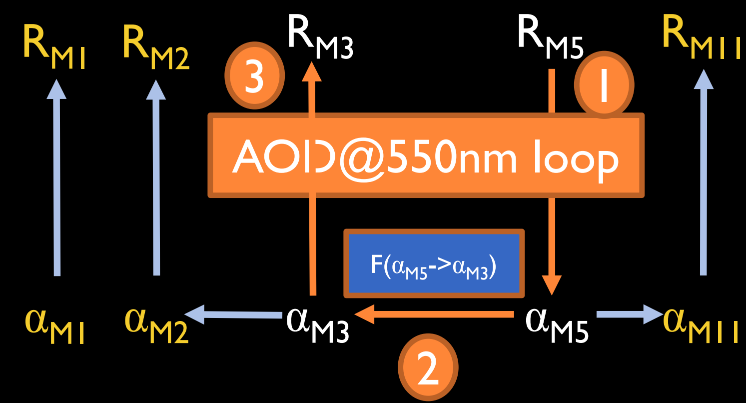


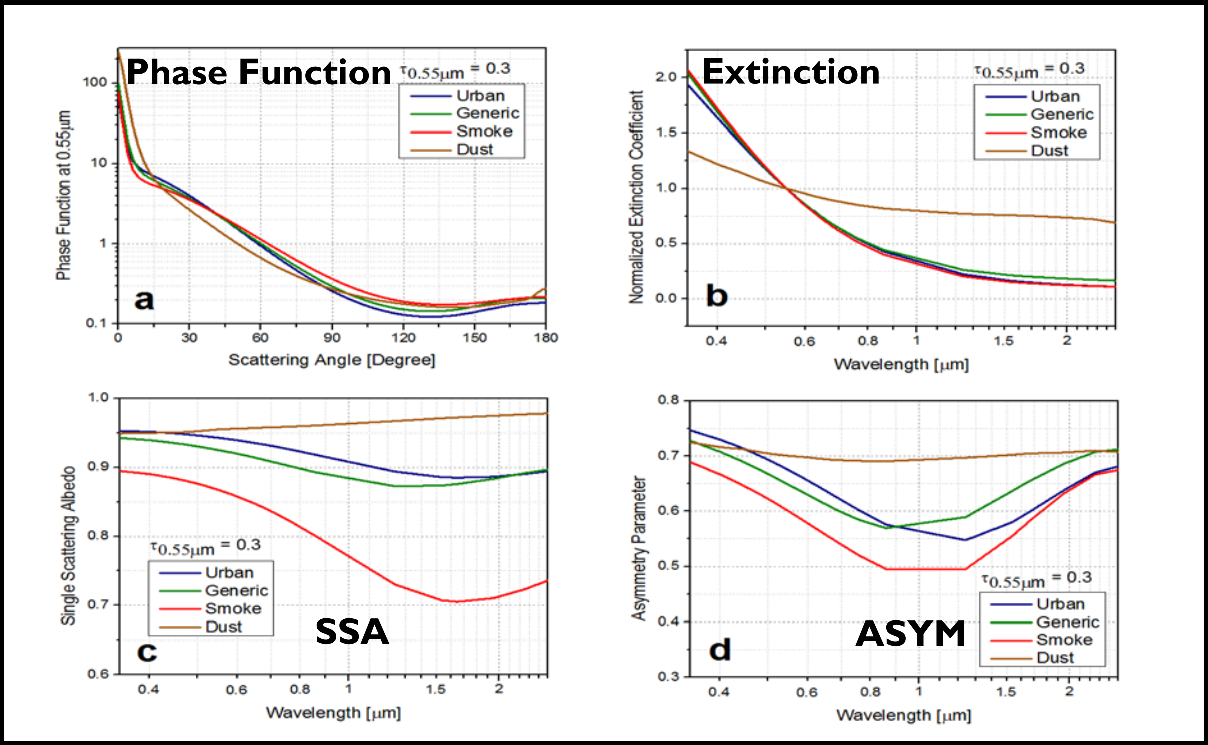




Major Causes of Retrieval Errors over Land

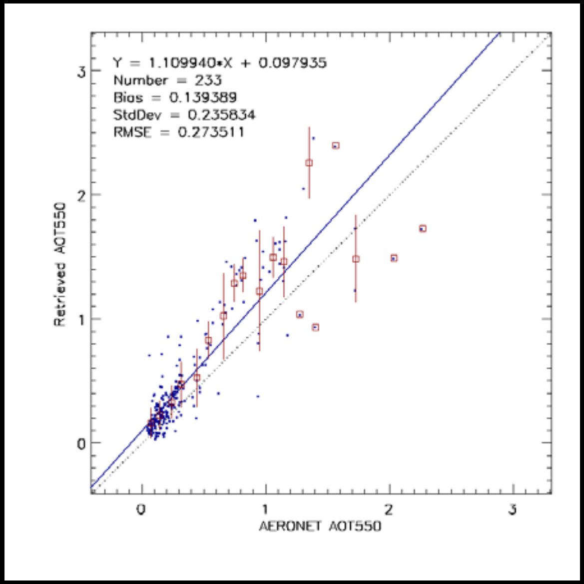
- Surface Reflectance
  - Simultaneous retrieval of AOD@550nm and surface reflectance with two reference channels
- Aerosol Models
  - Once AOD and surface reflectance are determined, difference between calculated and observed reflectance at residual channels are used to select optimal aerosol model from four candidates (urban, generic, smoke and dust)

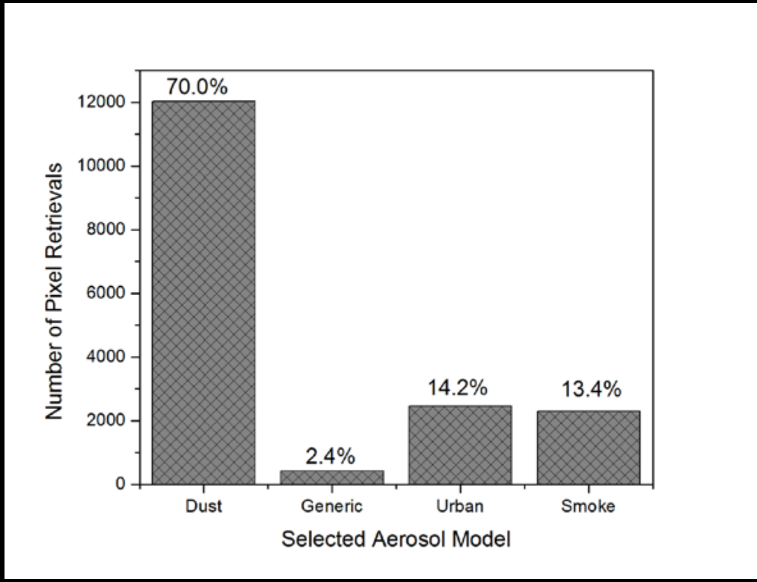


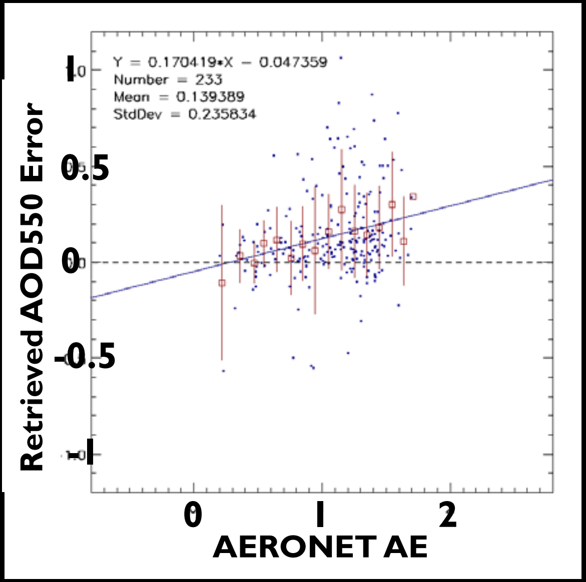


Beijing (1)

- AOD over-estimation
- Higher positive bias for fine-mode aerosol dominated cases (high AERONET AE)
- Majority (70%) of retrievals pick dust model

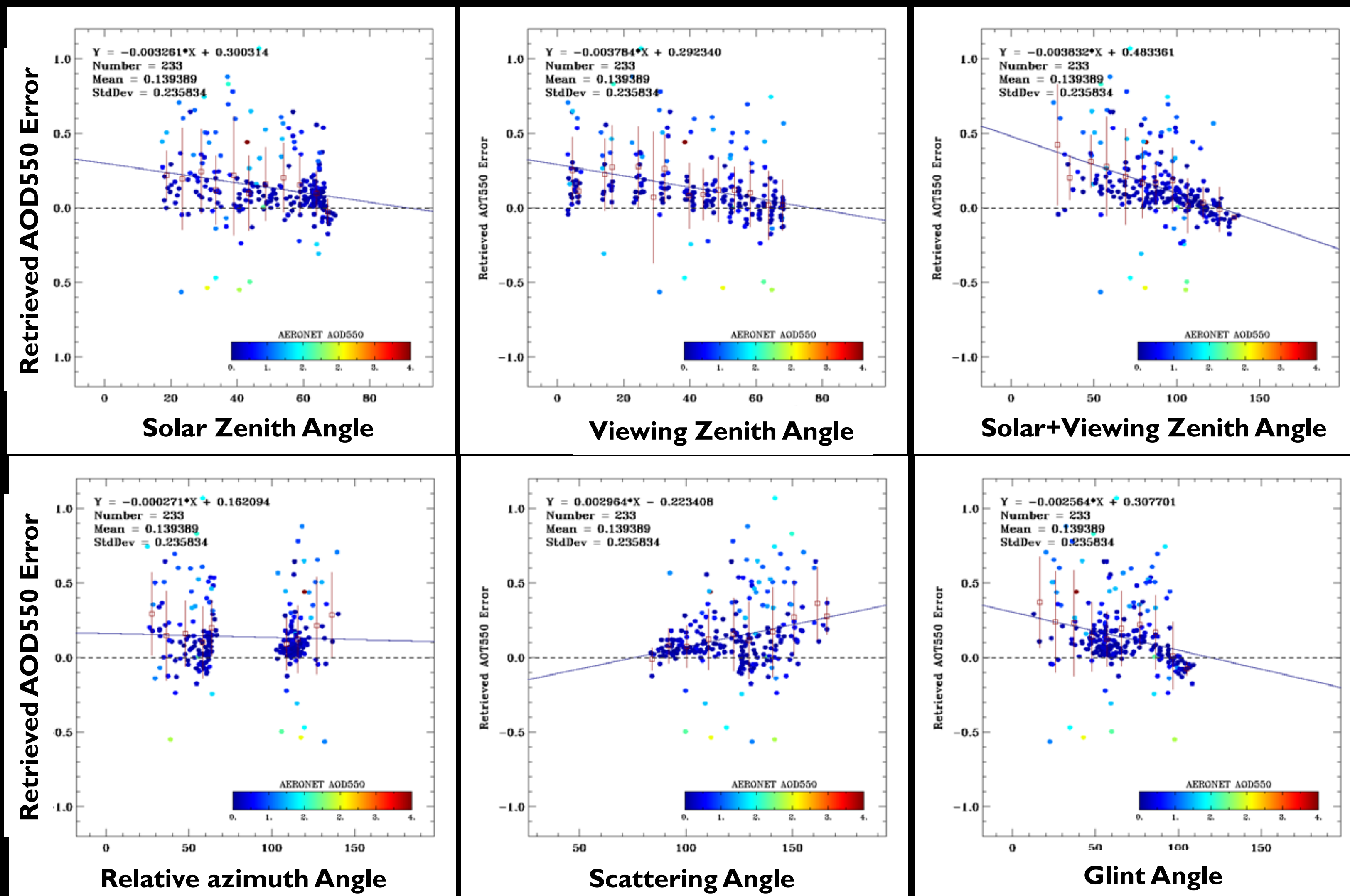






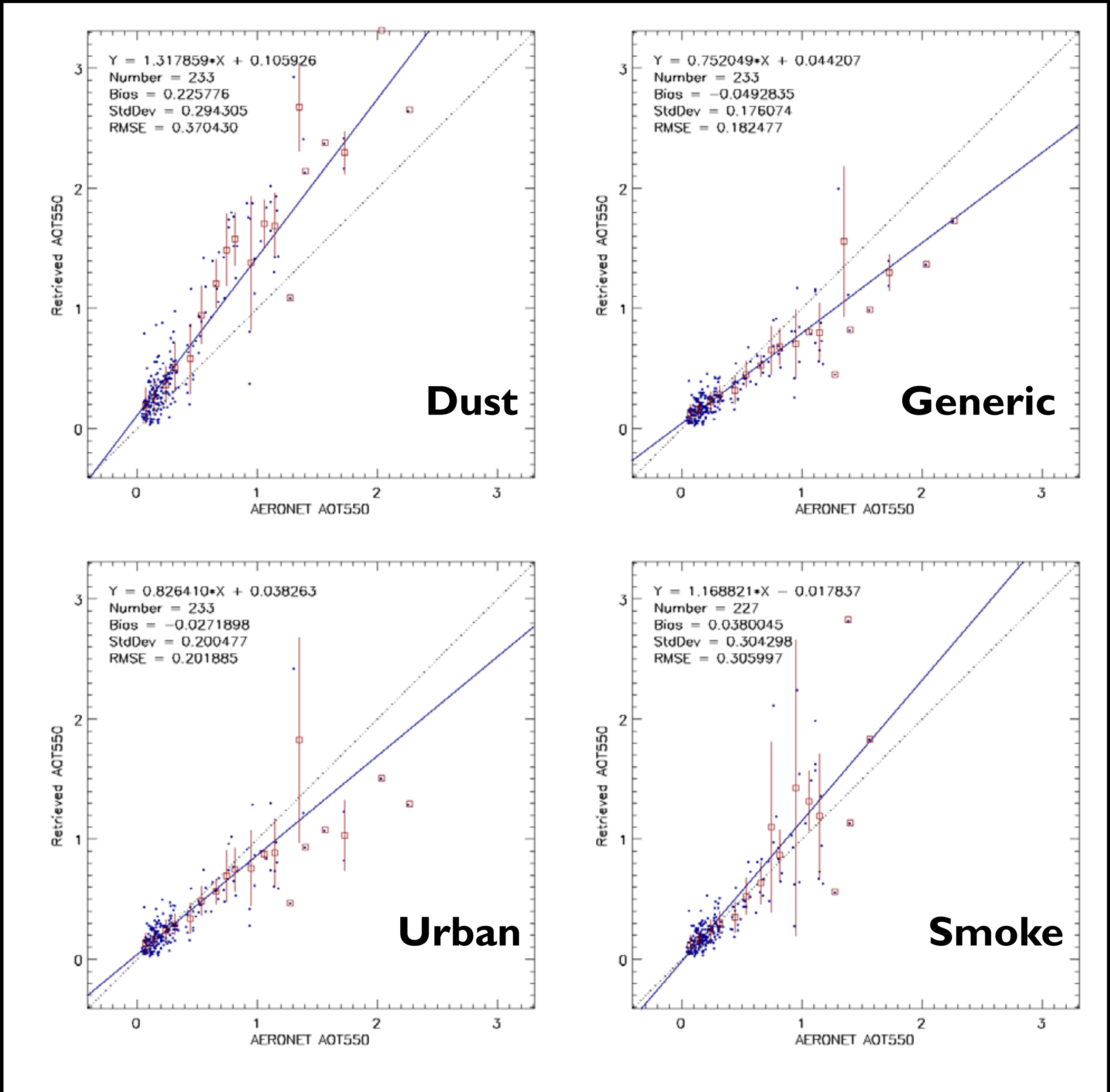
Beijing (2)

- Angular Dependence
  - Retrieval error against zenith, azimuth, scattering and glint angles



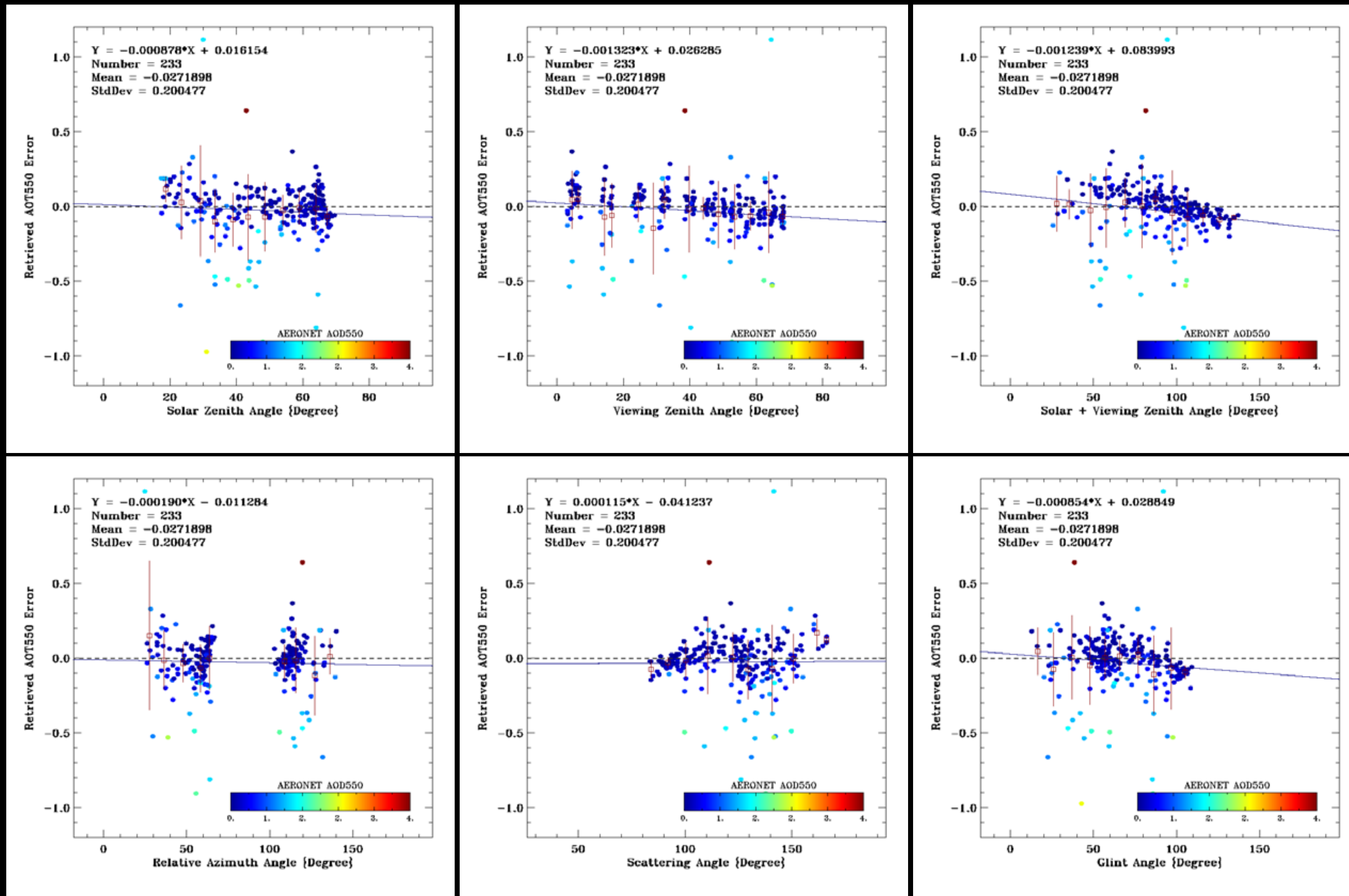
Beijing (3)

- Retrievals with fine-mode dominated aerosols would generate better results
- Problem in aerosol model selection



Beijing (4)

- Retrieval with urban aerosol model
  - Insignificant angular dependence of retrieval errors



Case Study (04/17/2013 05:57GMT)

Beijing (5)

Inputs:

PW	1.14337 cm
OZCONC	0.350851 atm-cm
PSL	1004.41 hpa
SFCTEMP	290.059 K
HGT	13.8458 m
WNDDIR	325.130 degree
WNDSPD	3.28555 m/s
REFLM1	0.322285
REFLM2	0.289493
REFLM3	0.258971
REFLM4	0.227863
REFLM5	0.235482
REFLM6	0.176977
REFLM7	0.282510
REFLM8	0.299651
REFLM9	0.00642178
REFLM10	0.299211
REFLM11	0.243100
BTM12	313.225 K
BTM15	292.967 K
BTM16	291.786
LAT	39.7449
LON	116.487
SOLZEN	37.2535 degree
SATZEN	57.5084 degree
SOLAZI	-134.700 degree
SATAZI	-93.8151 degree
HEIGHT	30.4856 m

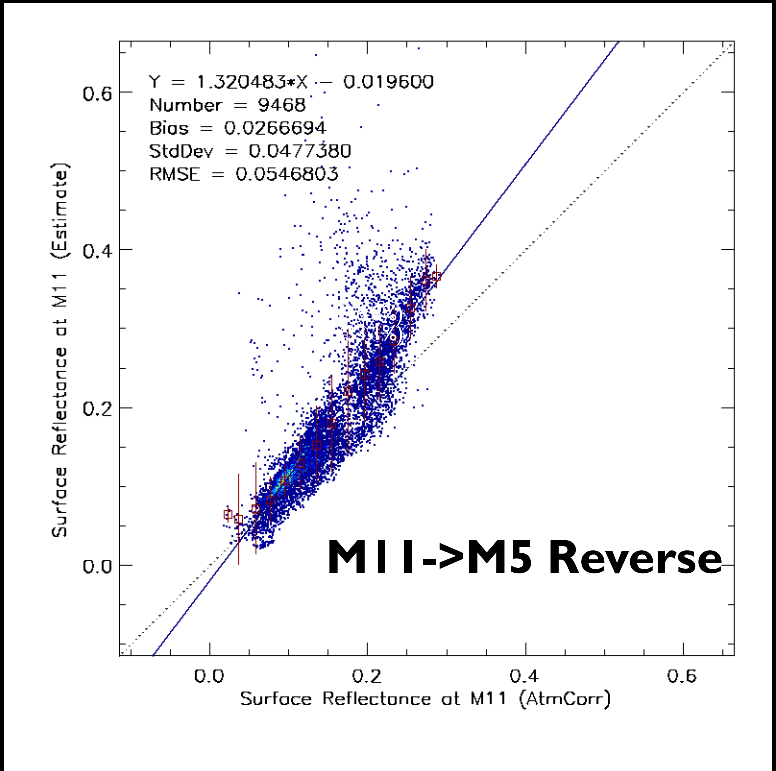
AERONET AOD550 = **0.727** AE=1.25

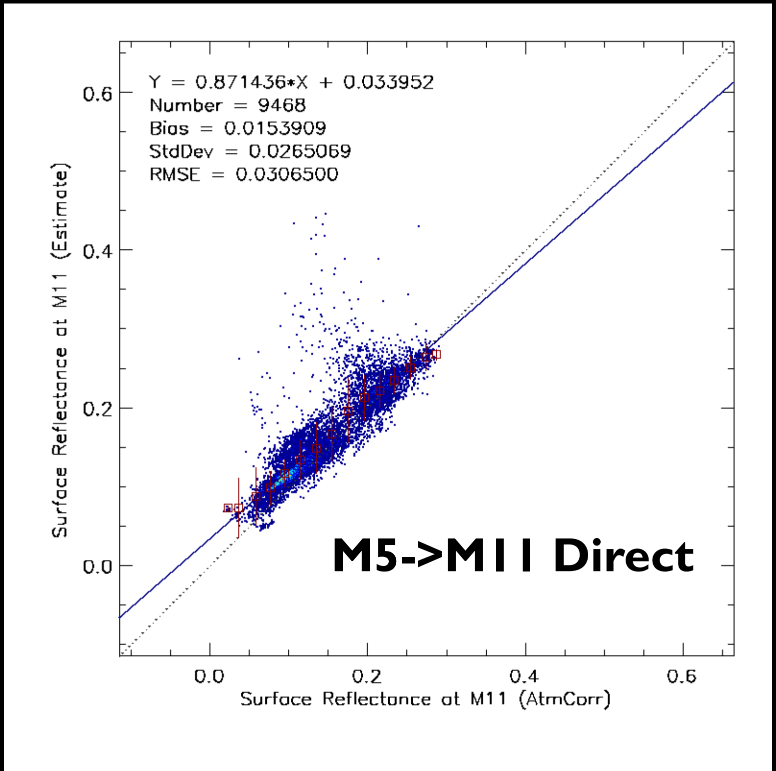
	Dust	Generic	Urban	Smoke
AOD550	**1.079**	**0.498**	**0.507**	**0.769**
Resi@M1	0.035	0.070	0.071	0.021
Resi@M2	0.016	0.038	0.038	0.021
Resi@M11	***0.137***	***0.528***	***0.527***	***0.700***
Residual	**0.082**	**0.309**	**0.308**	**0.404**
SfcR@M1	0.0929	0.1318	0.1304	0.1547
SfcR@M2	0.1030	0.1436	0.1421	0.1675
SfcR@M3	**0.1160**	**0.1577**	**0.1561**	**0.1822**
SfcR@M5	0.1786	0.2304	0.2285	0.2609
SfcR@M11	**0.3202**	**0.4434**	**0.4389**	**0.5160**

Residual dominated by M11 (2.13μm)

Beijing (6)

- Revise the estimation of surface reflectance at M11
  - Current scheme uses the reverse of M11->M5 relationship
  - Derive a new direct relationship from M5 to M11





Case Study - Revisit

Beijing (7)

AERONET AOD550 = 0.727 AE=1.25

- Compared with current EPS retrieval, estimated surface reflectance at M11 for fine mode aerosols is much closer to the correct value, and the residual is not significantly biased to M11 band.

- Dust is still the best solution.

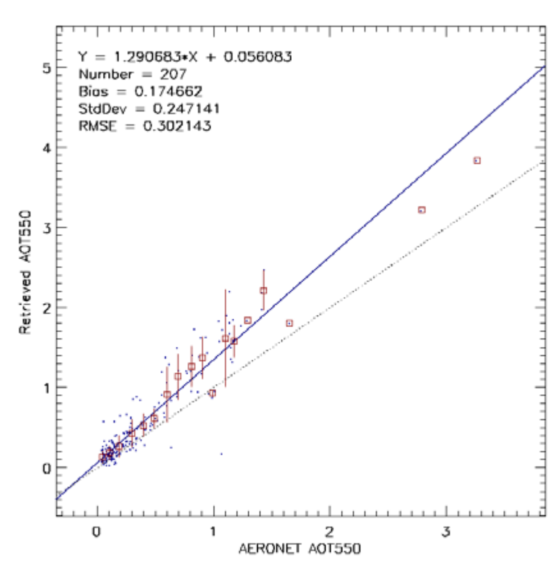
- Average of two best solutions (dust and generic weighed by residual) 0.794 is closer to the AERONET measurement.

	Dust	Generic	Urban	Smoke
AOD550	**1.079**	**0.498**	**0.507**	**0.769**
Resi@M1	0.035	0.070	0.071	0.021
Resi@M2	0.016	0.038	0.038	0.021
Resi@M11	***0.056***	***0.038***	***0.041***	***0.087***
Residual	**0.049**	**0.051**	**0.052**	**0.053**
SfcR@M1	0.0929	0.1318	0.1304	0.1547
SfcR@M2	0.1030	0.1436	0.1421	0.1675
SfcR@M3	0.1160	0.1577	0.1561	0.1822
SfcR@M5	0.1786	0.2304	0.2285	0.2609
SfcR@M11	**0.2472**	**0.2952**	**0.2934**	**0.3234**

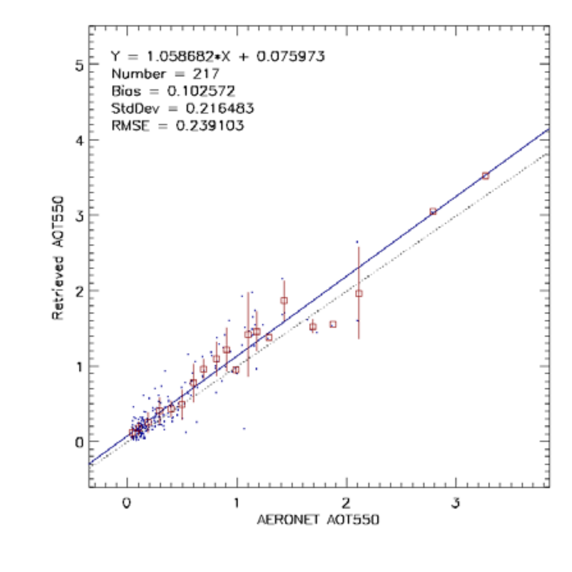
Beijing (8)

- Retrieval with new M5->M11 surface relationship
  - Retrieval over Beijing is slightly improved by using new M5->M11 surface reflectance relationship
  - With modification, less dust retrievals are picked as the best solution: dust 36% (70%); generic 2% (2%); urban 30% (14%); smoke 32% (14%)
  - More improvement is achieved if best two solutions are weighted averaged by the residual

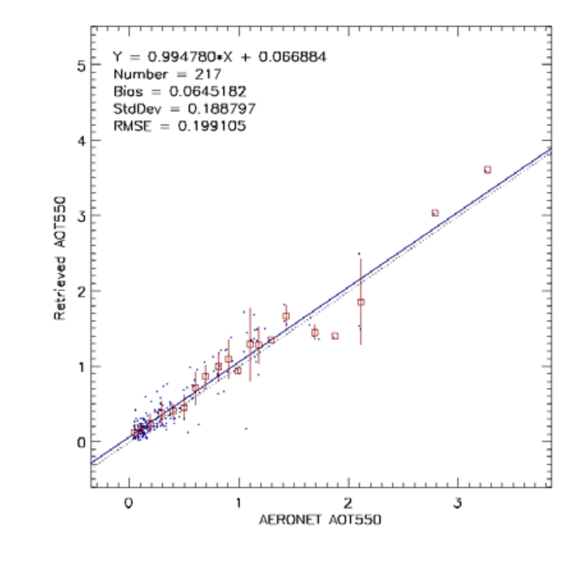
EPS Original Retrieval



New M5->M11 Relationship

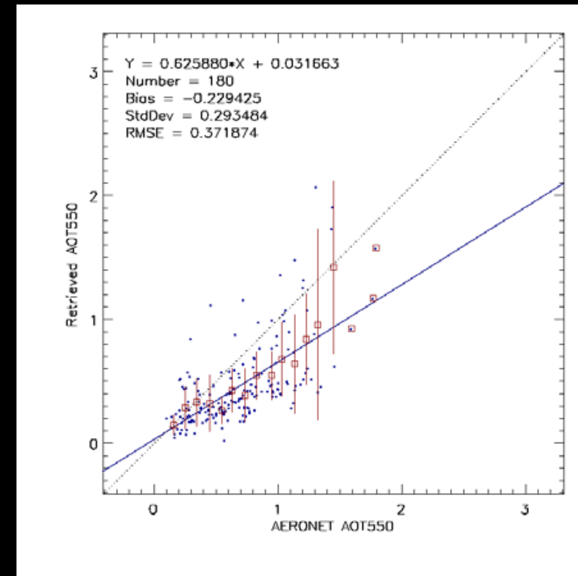


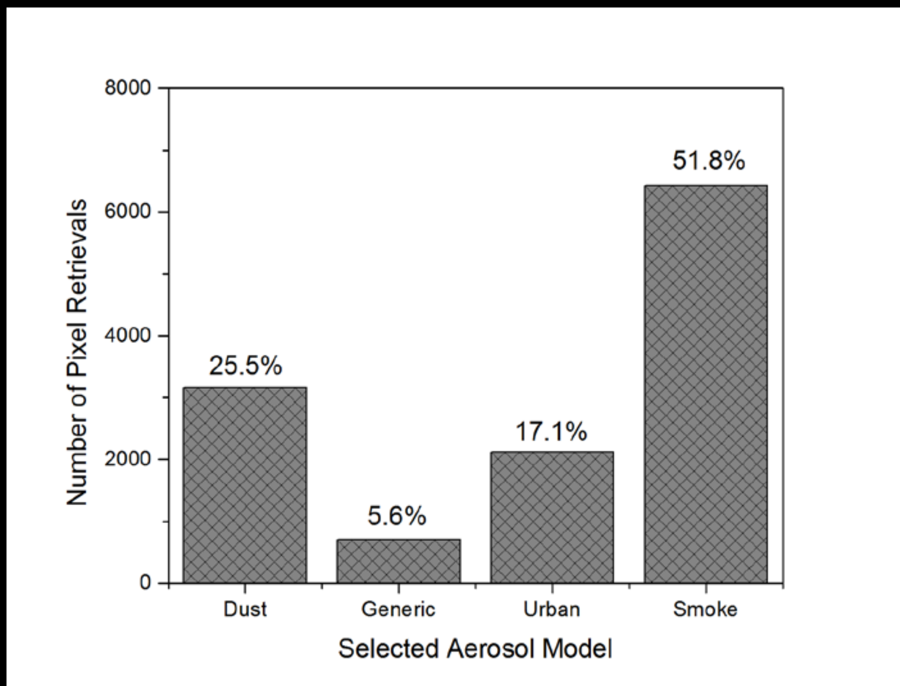
New M5->M11 Relationship
Average of best two solutions

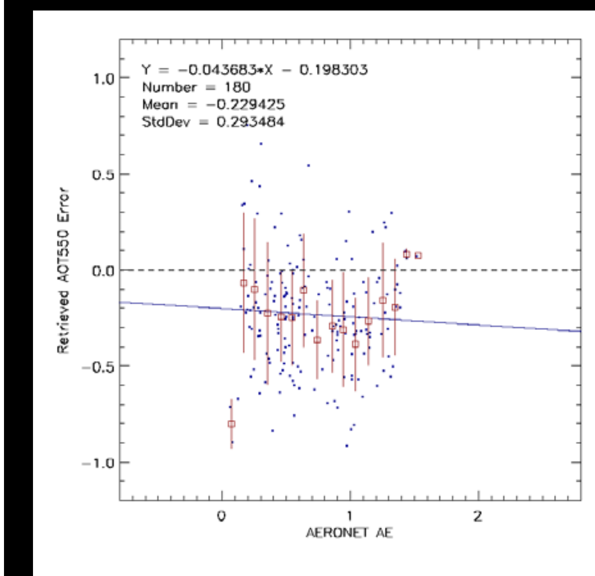


Ilorin (1)

- AOD under-estimation
- Majority (52%) of retrievals pick smoke model, while AERONET Angstrom Exponent shows many dust cases dominated by low AE

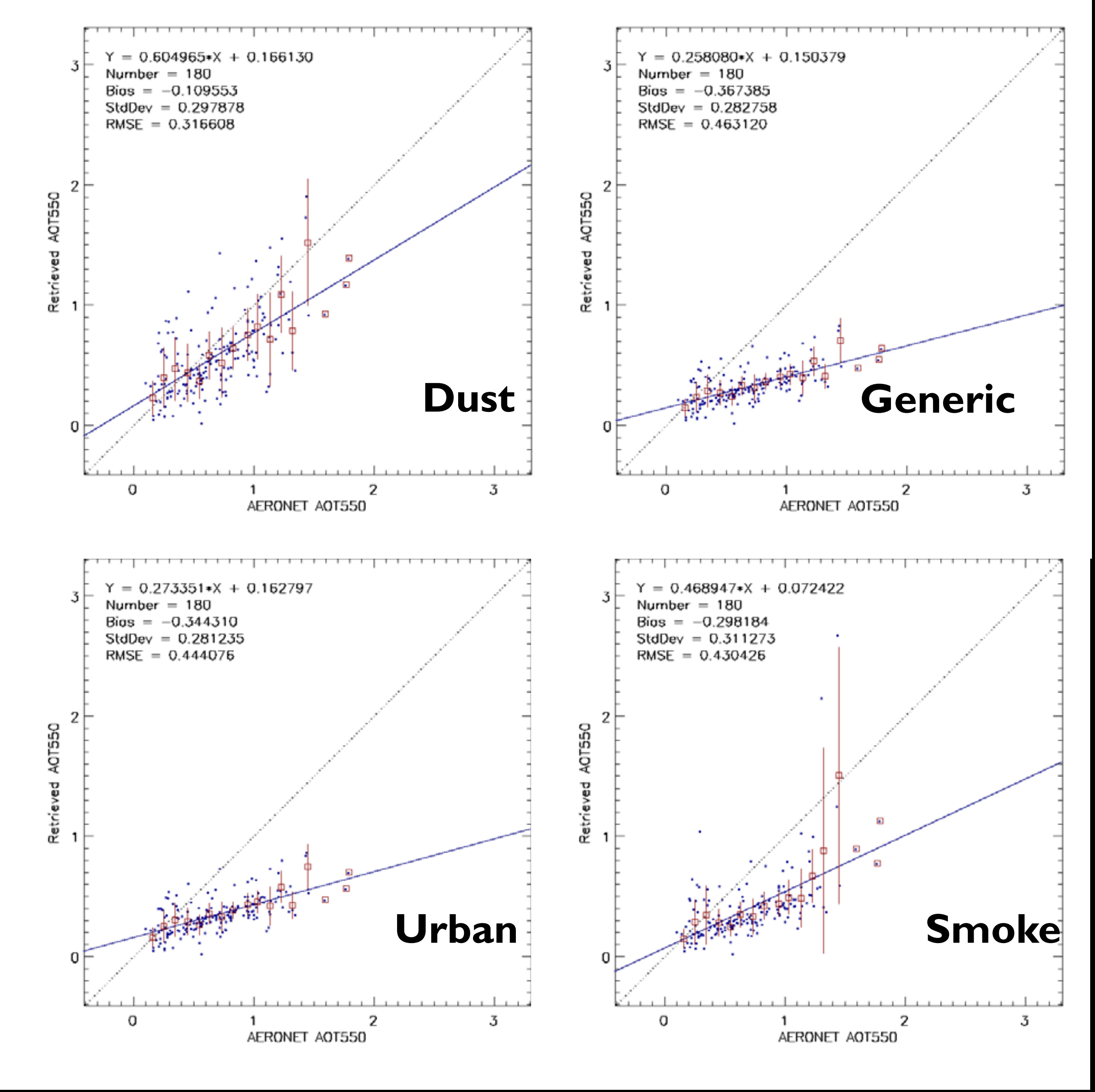






Ilorin (2)

- Retrievals with dust model would generate better results
- Problem in aerosol model selection



Case Study (12/18/2012)

Ilorin (3)

Inputs:

PW	1.51776	cm
OZCONC	0.253983	atm-cm
PSL	966.612	hpa
SFCTEMP	306.494	K
HGT	331.854	m
WNDDIR	212.892	degree
WNDSPD	3.59268	m/s
REFLM1	0.262927	
REFLM2	0.229963	
REFLM3	0.200540	
REFLM4	0.177515	
REFLM5	0.165452	
REFLM6	0.175586	
REFLM7	0.270887	
REFLM8	0.329367	
REFLM9	0.0115250	
REFLM10	0.285928	
REFLM11	0.195022	
BTM12	316.778	K
BTM15	304.850	K
BTM16	303.218	K
LAT	8.28619	
LON	4.16135	
SOLZEN	40.53	degree
SATZEN	40.63	degree
SOLAZI	-141.99	degree
SATAZI	-98.14	degree
HEIGHT	371.975	m

AERONET AOD550 = **1.186** AE = 0.34

	Dust	Generic	Urban	Smoke
AOD550	**1.254**	**0.570**	**0.606**	**0.769**
Resi@M1	0.023	0.035	0.036	0.009
Resi@M2	0.006	0.019	0.019	0.005
Resi@M11	***0.201***	***0.194***	***0.193***	***0.198***
Residual	**0.1167**	**0.1141**	**0.1139**	**0.1143**
SfcR@M1	0.0269	0.0739	0.0738	0.0810
SfcR@M2	0.0289	0.0812	0.0811	0.0891
SfcR@M3	**0.0364**	0.0921	0.0919	0.1005
SfcR@M5	0.0677	0.1355	0.1353	0.1457
SfcR@M11	**0.1320**	**0.1728**	**0.1726**	**0.1789**

Residual dominated by M11, difference is very small, hard to select correct model; dust high AOD associated with low surface reflectance

Ilorin (4)

Case Study (1/9/2013)

Inputs:

PW	2.16383
OZCONC	0.246923
PSL	965.934
SFCTEMP	308.135
HGT	357.818
WNDDIR	217.665
WNDSPD	2.76619
REFLM1	0.206205
REFLM2	0.180127
REFLM3	0.156760
REFLM4	0.141377
REFLM5	0.127727
REFLM6	0.164988
REFLM7	0.249692
REFLM8	0.294279
REFLM9	0.00300334
REFLM10	0.228132
REFLM11	0.133368
BTM12	311.346
BTM15	303.350
BTM16	301.711
LAT	8.08027
LON	4.37263
SOLZEN	36.08
SATZEN	20.74
SOLAZI	--146.94
SATAZI	-97.84
HEIGHT	395.466

AERONET AOD550 = **1.273** AE = 0.578

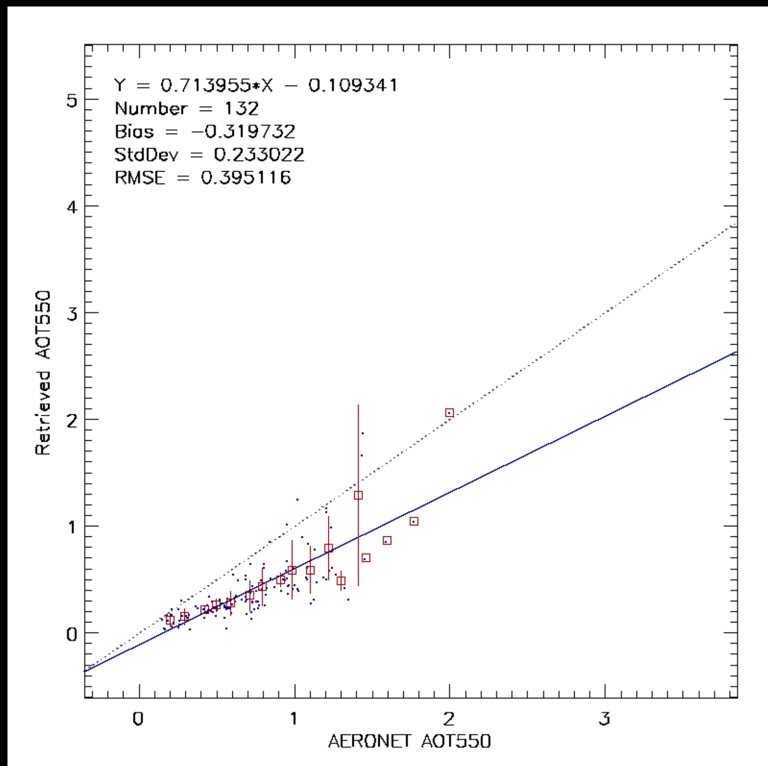
	Dust	Generic	Urban	Smoke
AOD550	**1.232**	**0.620**	**0.679**	**0.700**
Resi@M1	***0.065***	***0.098***	***0.096***	***0.056***
Resi@M2	0.017	0.039	0.037	0.026
Resi@M11	0.015	0.005	0.007	0.014
Residual	**0.040**	**0.061**	**0.060**	**0.036**
SfcR@M1	0.0115	0.0504	0.0499	0.0558
SfcR@M2	0.0136	0.0540	0.0535	0.0596
SfcR@M3	**0.0207**	0.0617	0.0612	0.0673
SfcR@M5	0.0463	0.0968	0.0962	0.1037
SfcR@M11	0.1139	0.1450	0.1446	0.1492

Residual dominated by M1, difference is very small, hard to select correct model; dust high AOD associated with low surface reflectance

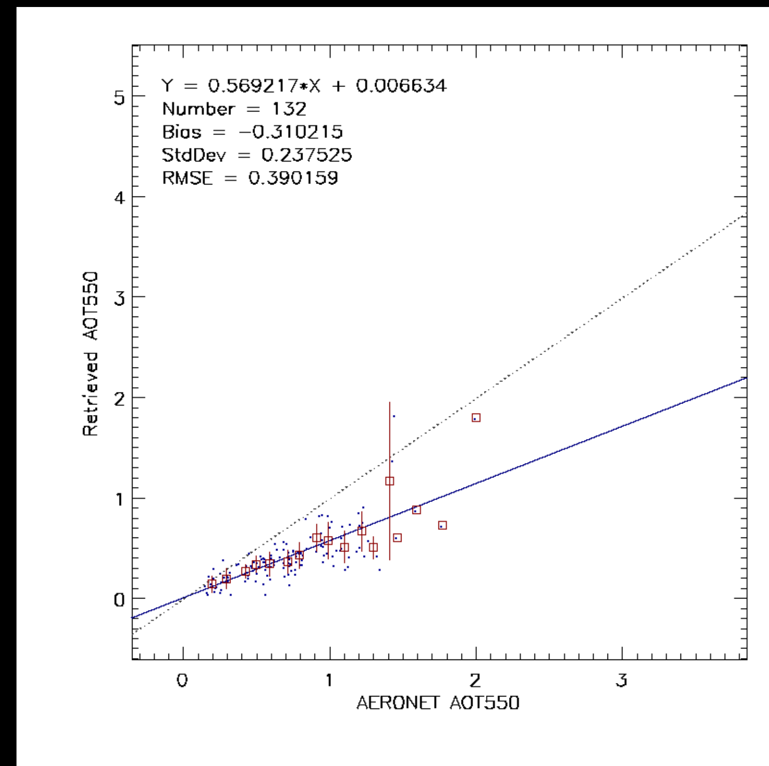
Ilorin (5)

- Retrieval with new M5->M11 surface relationship
  - No improvement

EPS Original Retrieval

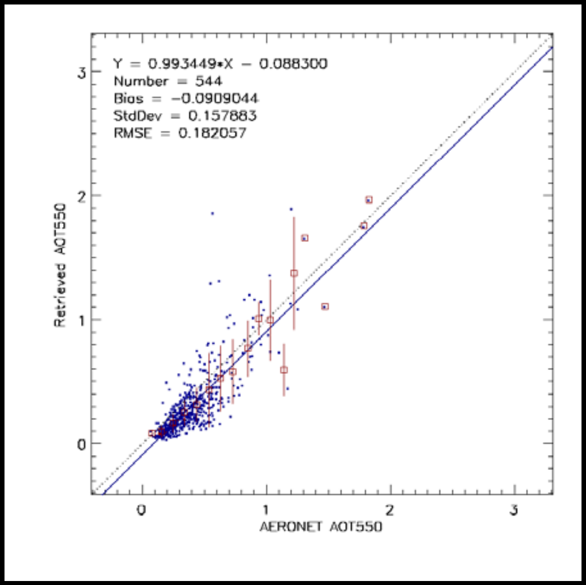


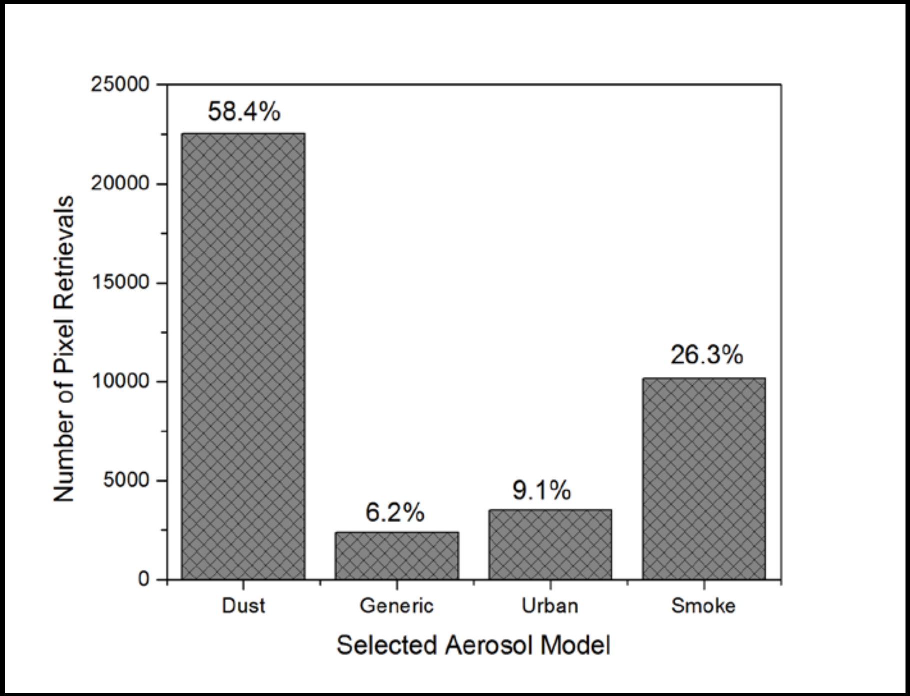
New M5->M11 Relationship

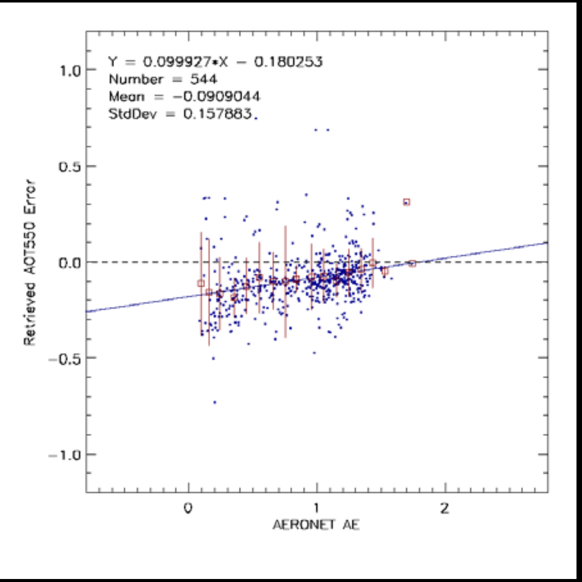


Jaipur (1)

- AOD small under-estimation
- 58% of retrievals pick dust model and 26% of retrievals pick smoke.

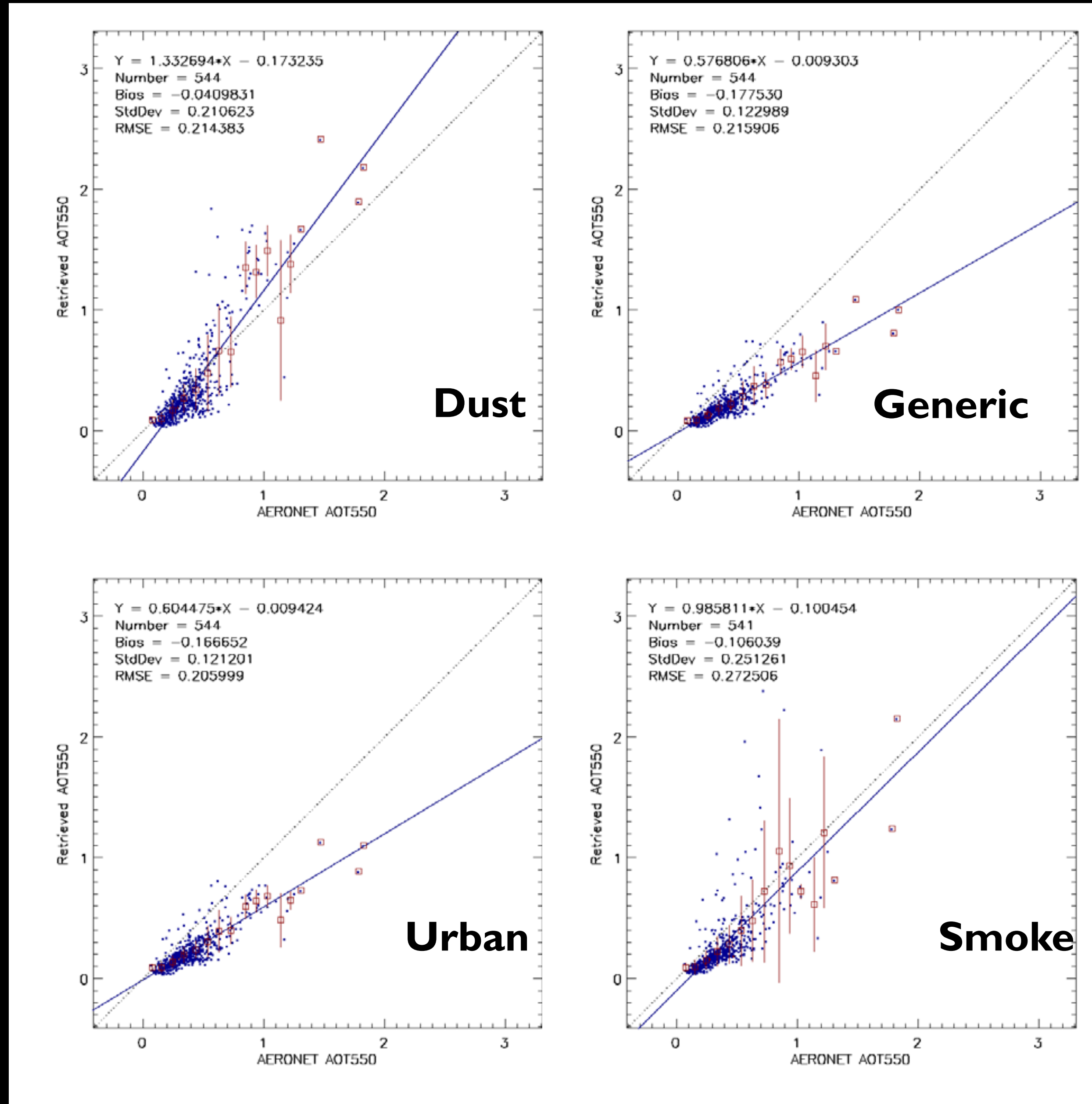






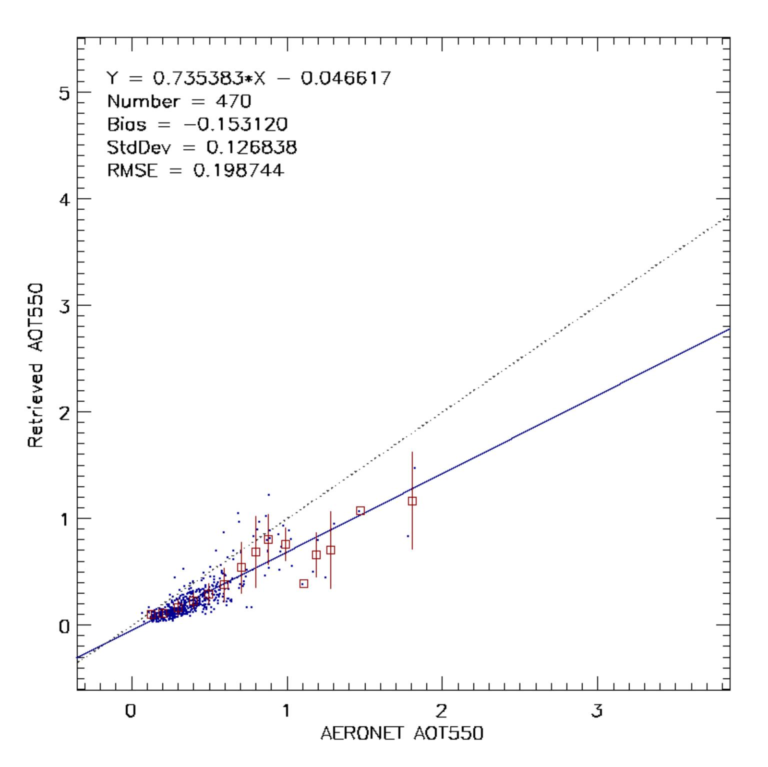
Jaipur (2)

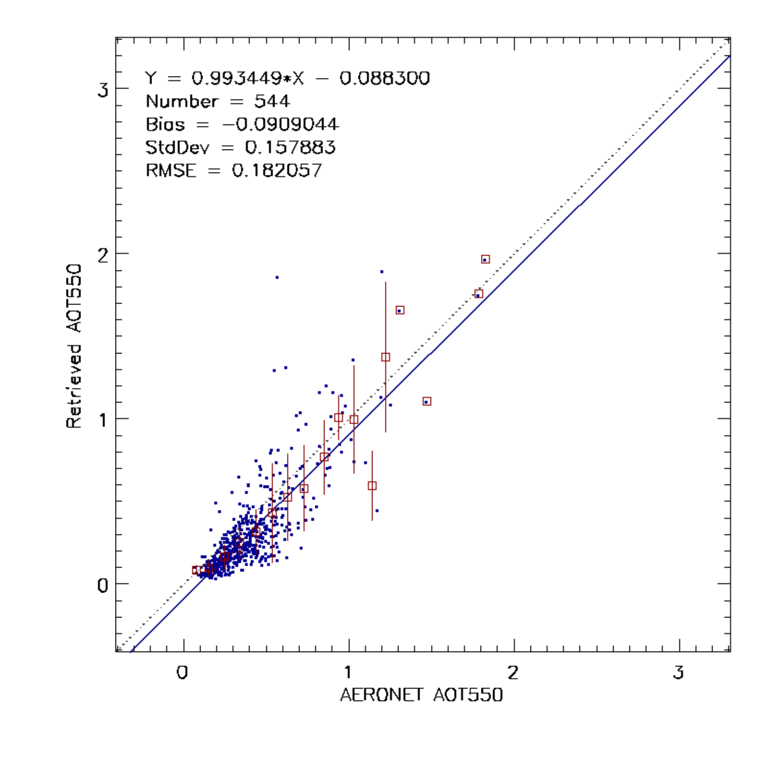
- Dust and smoke models give better results than generic and urban models



Jaipur (3)

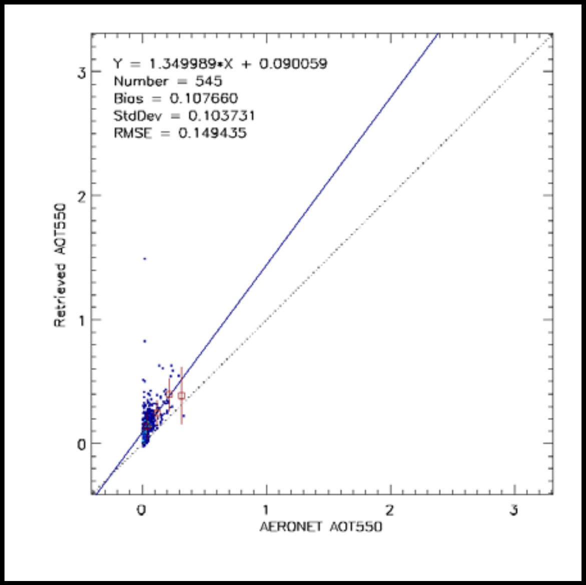
- Validation statistics depend on the satellite-ground matching method
  - Left: 27.5 km radius on satellite retrievals centered on the Jaipur station, at least 750 high quality pixel retrievals
  - Right: 5 km radius, at least 5 high quality retrievals

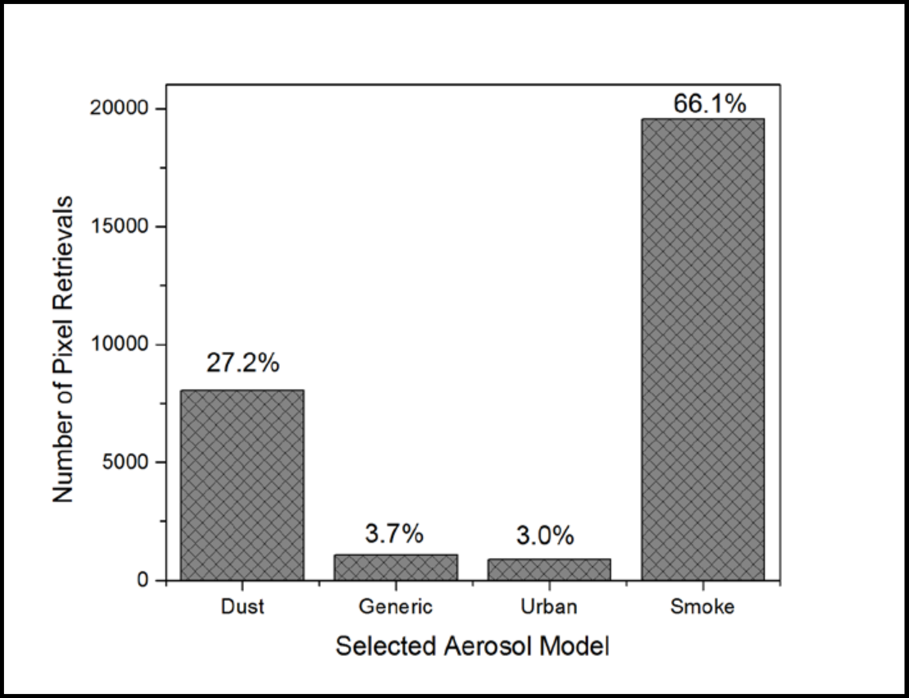


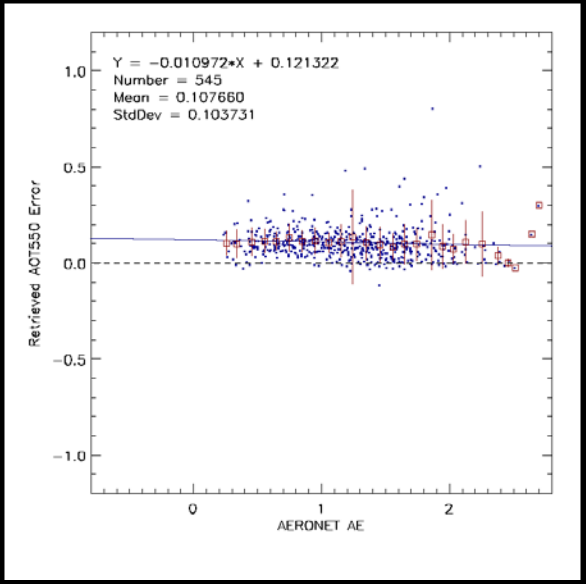


Railroad Valley (1)

- AOD over-estimation
- Low AOD dominated area
- 66% of retrievals pick smoke model and 27% of retrievals pick dust.

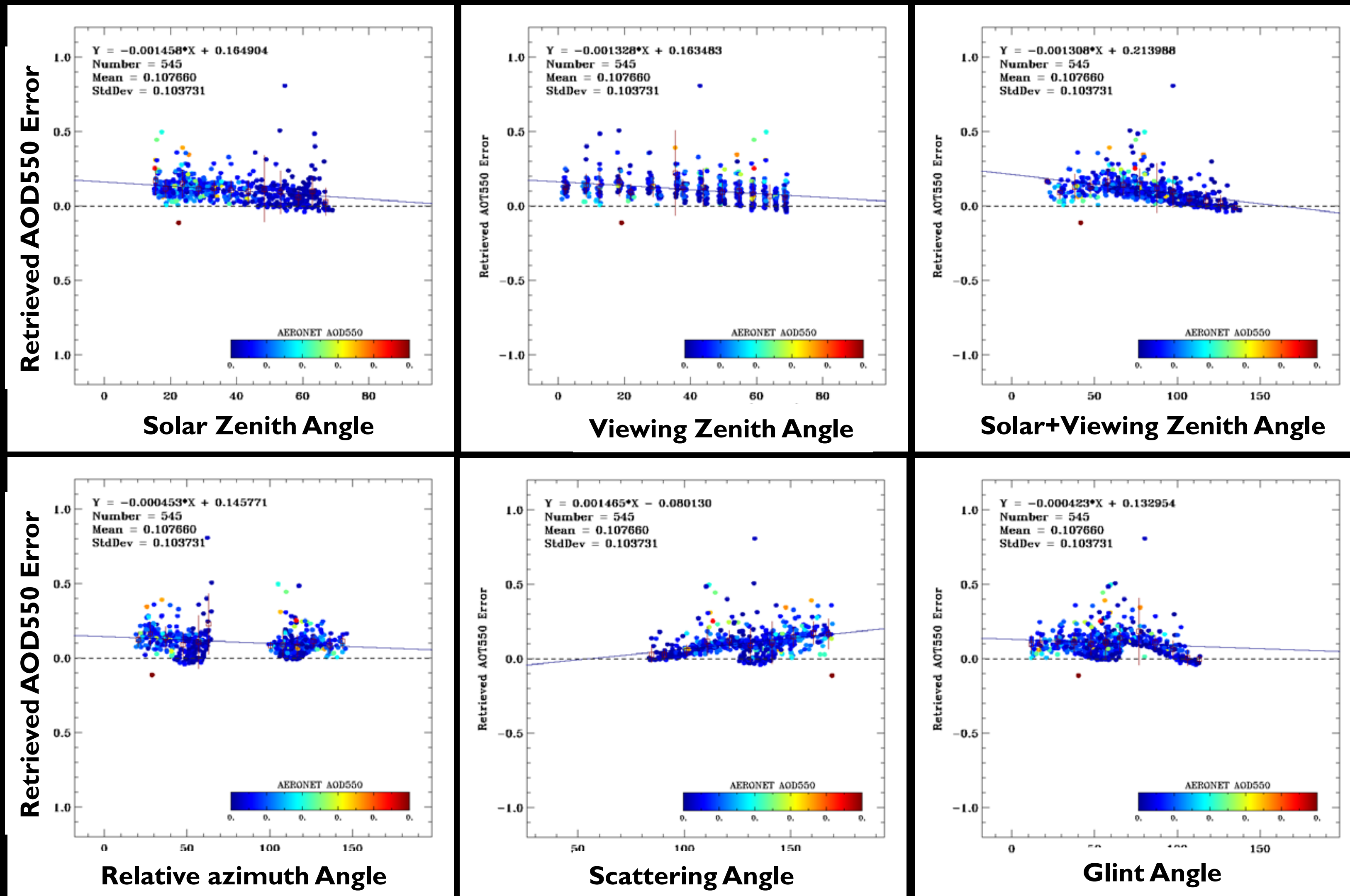






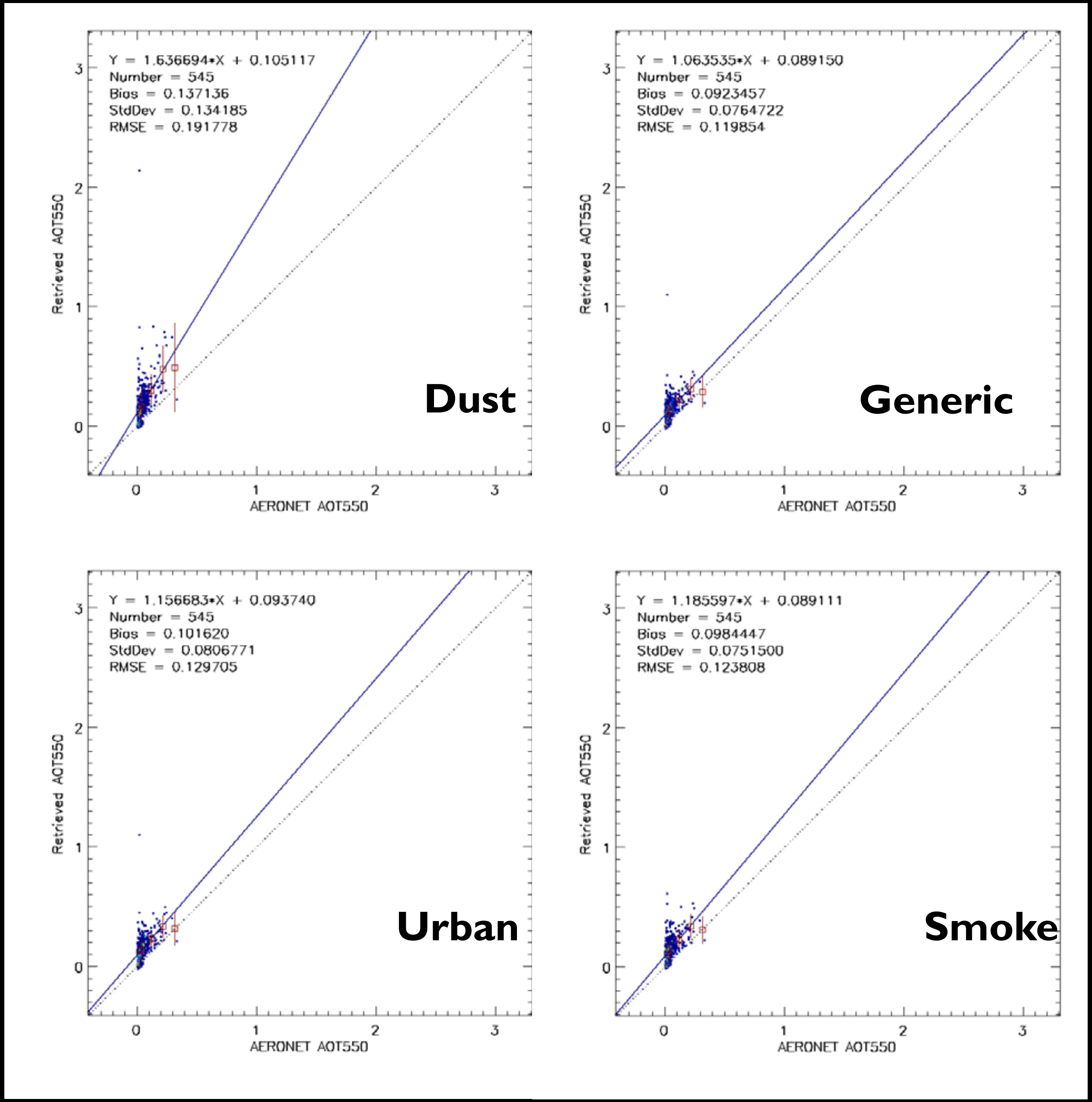
Railroad Valley (2)

- Angular Dependence
  - Retrieval error against zenith, azimuth, scattering and glint angles



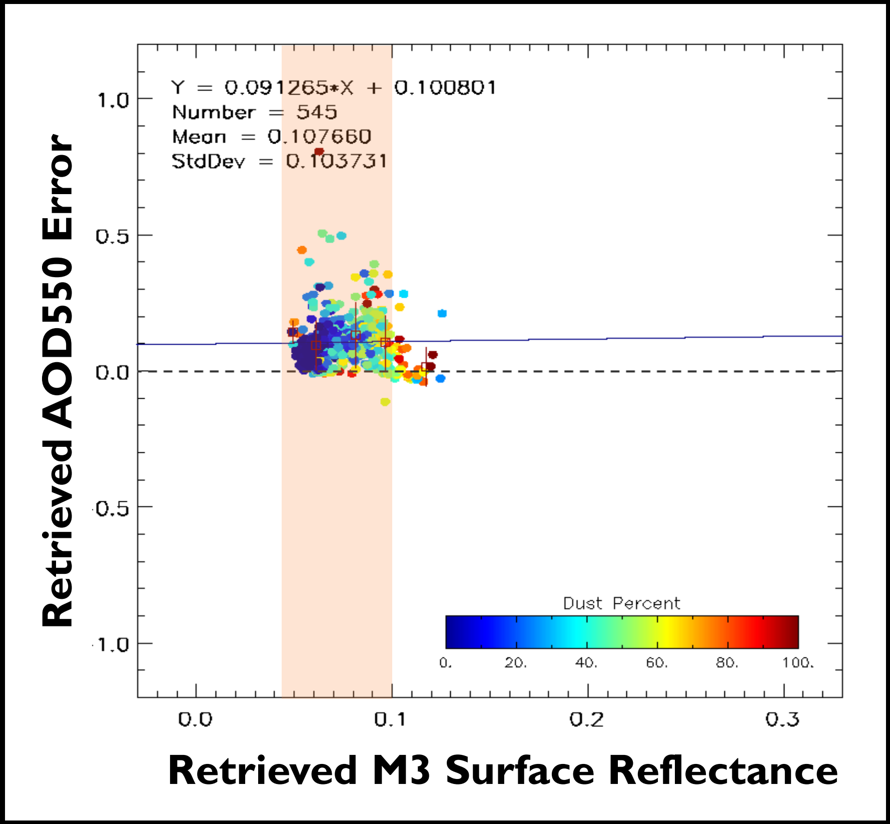
Railroad Valley (3)

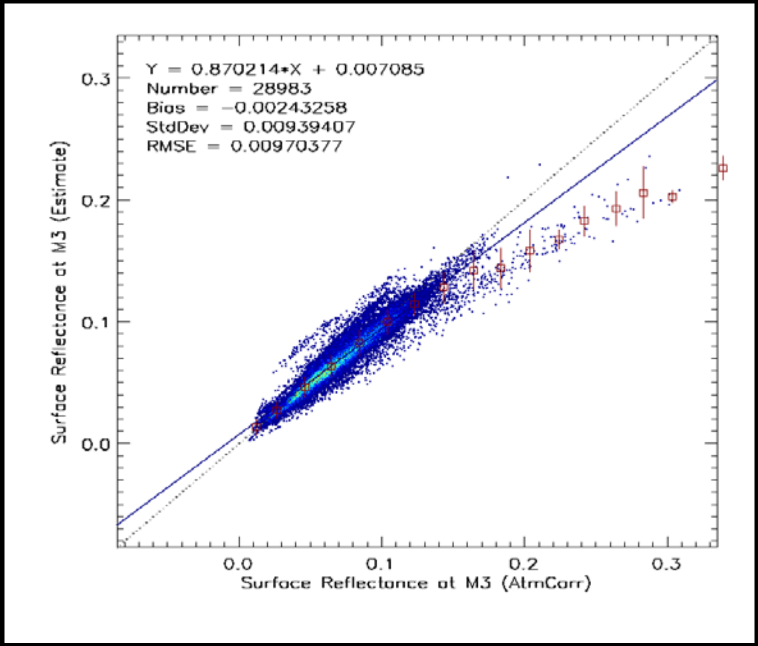
- All aerosol models overestimate.

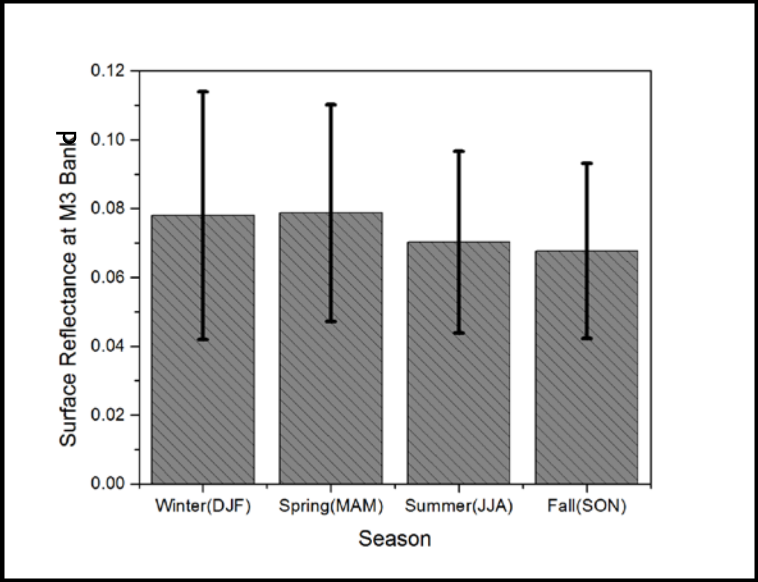


Railroad Valley (4)

- Surface reflectance
  - Retrieve surface reflectance from low AOD cased via atmospheric correction
  - Evaluation of the surface reflectance relationship (M5->M3 derived globally) over this station does not reveal significant error
  - SfcRef@M3 of majority retrievals fall within expected range
  - No significant season variation







SfcRef@M3: 0.072±0.029

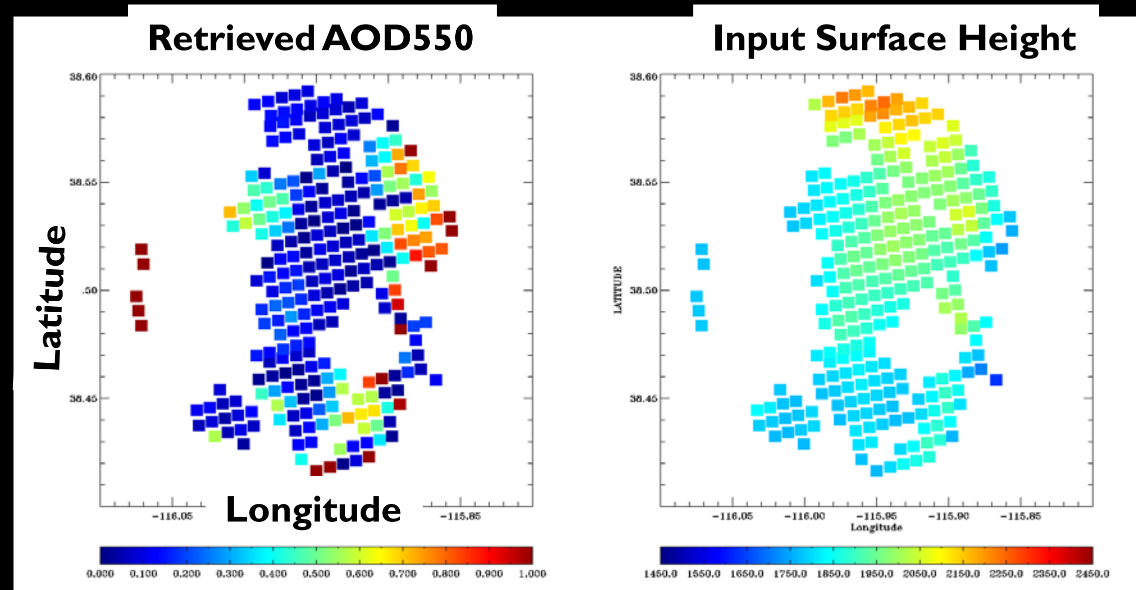
Railroad Valley (5)

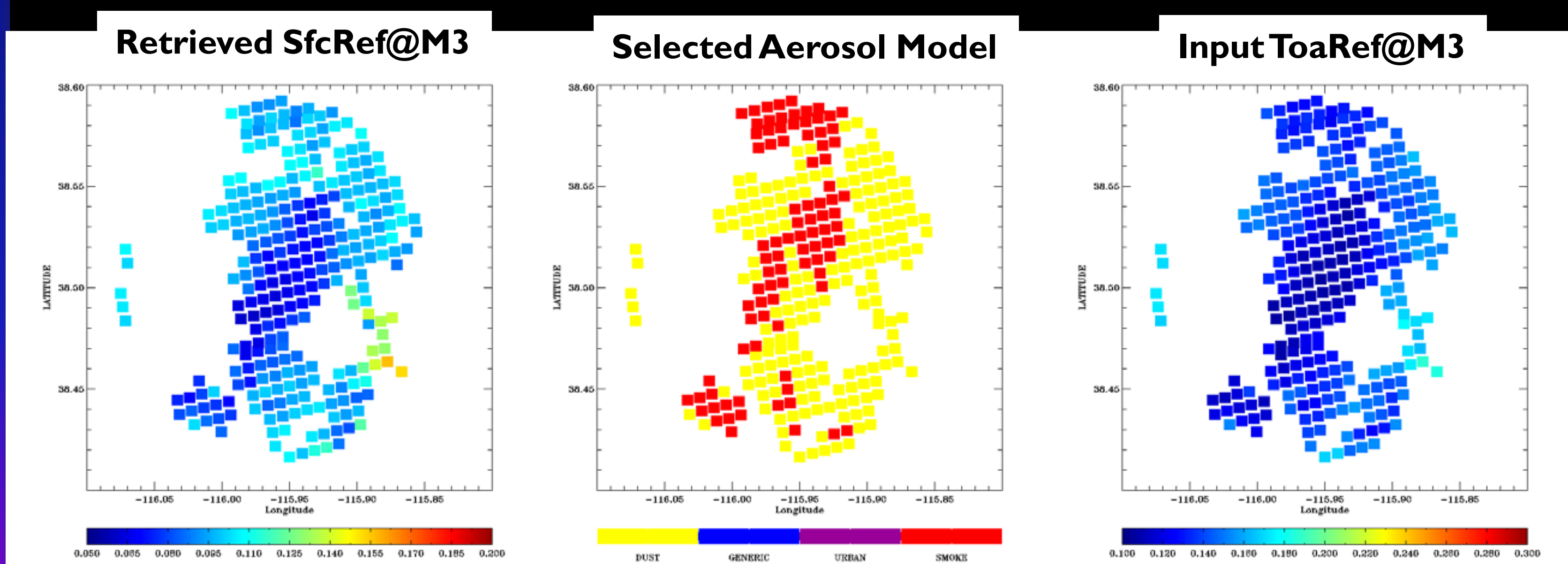
- Rugged terrain

Railroad Valley (6)

- **Case Study**

Date:	2013.157
AERONET AOD550:	0.052
EPS Mean AOD550:	0.276
Solar Zenith Angle:	19.10°
Viewing Zenith Angle:	11.89°
Solar Azimuth Angle:	-142.06°
Viewing Azimuth Angle:	78.16°
Scattering Angle:	150.83°
Glint Angle:	12.54°

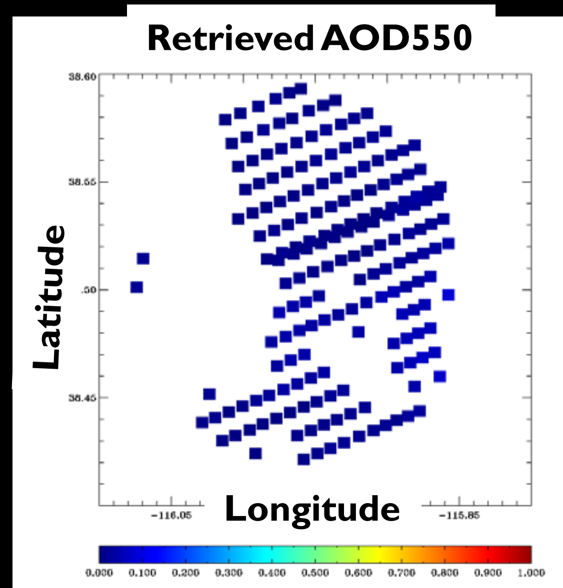


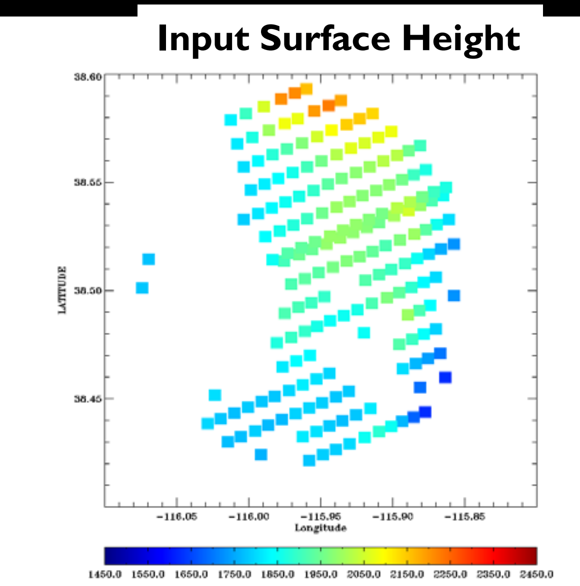


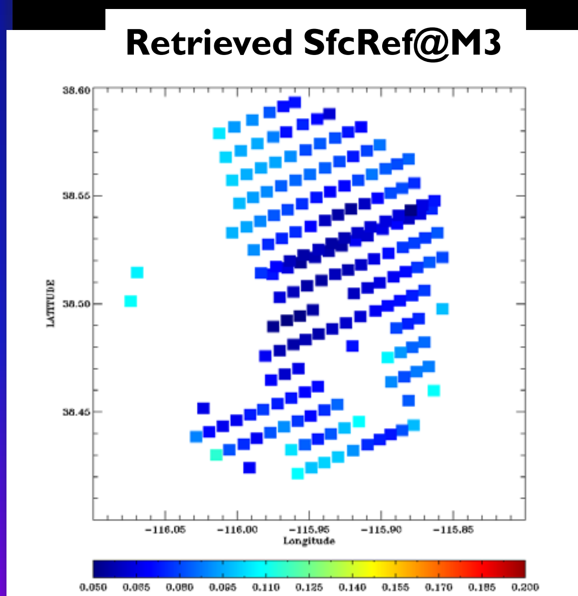
Railroad Valley (6)

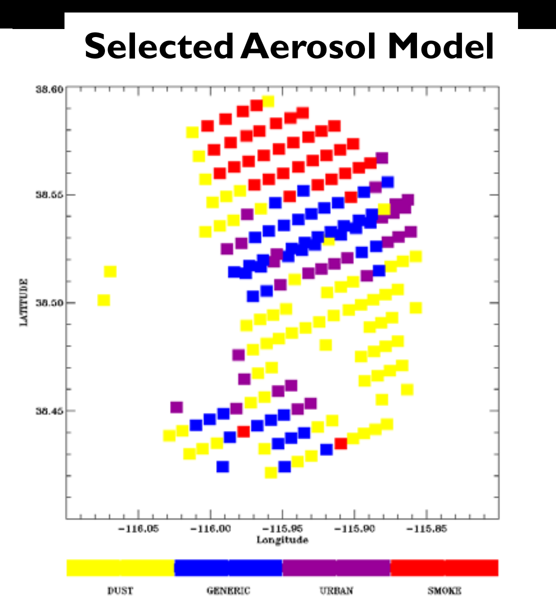
- **Case Study**

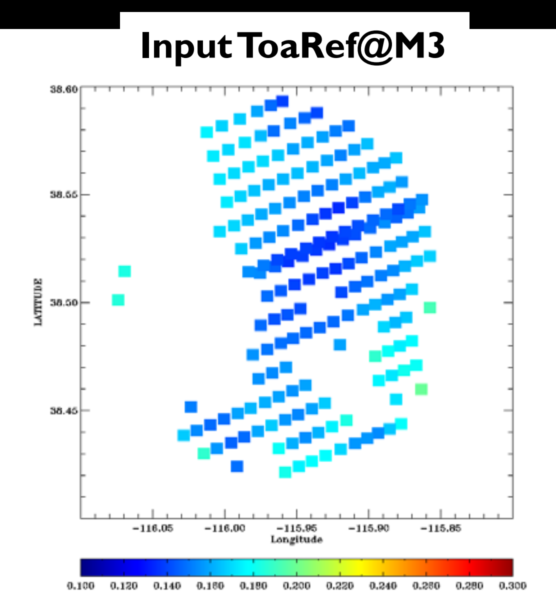
Date:	2012.328
AERONET AOD550:	0.009
EPS Mean AOD550:	0.017
Solar Zenith Angle:	59.20°
Viewing Zenith Angle:	59.09°
Solar Azimuth Angle:	-175.33°
Viewing Azimuth Angle:	70.62°
Scattering Angle:	87.87°
Glint Angle:	55.71°









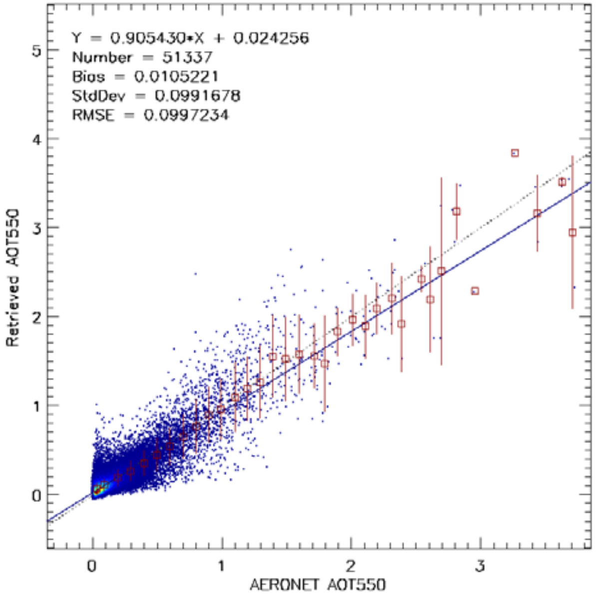


Summary

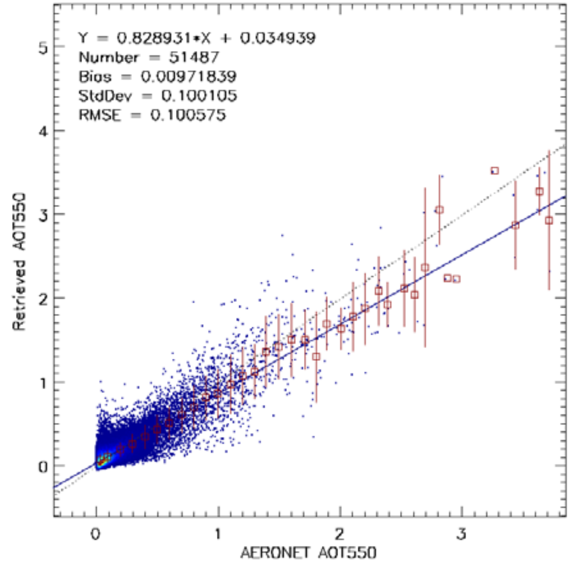
- VIIRS Enterprise Processing System AOD retrieval over land is evaluated using AERONET measurements over different geographic regions.
- Aerosol model selection can be improved by introducing a new set of surface reflectance relationship over East Asia.
- Lack a more absorbing dust model might be the cause of the negative bias over Africa.
- Evaluation of retrieval performance is sensitive to the validation domain selection over certain areas.
- Retrieval would have difficulty over rugged terrain areas.

Global Evaluation

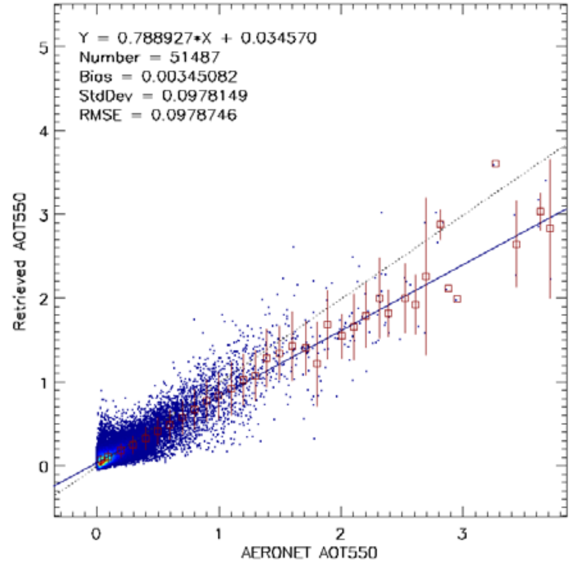
EPS Original Retrieval



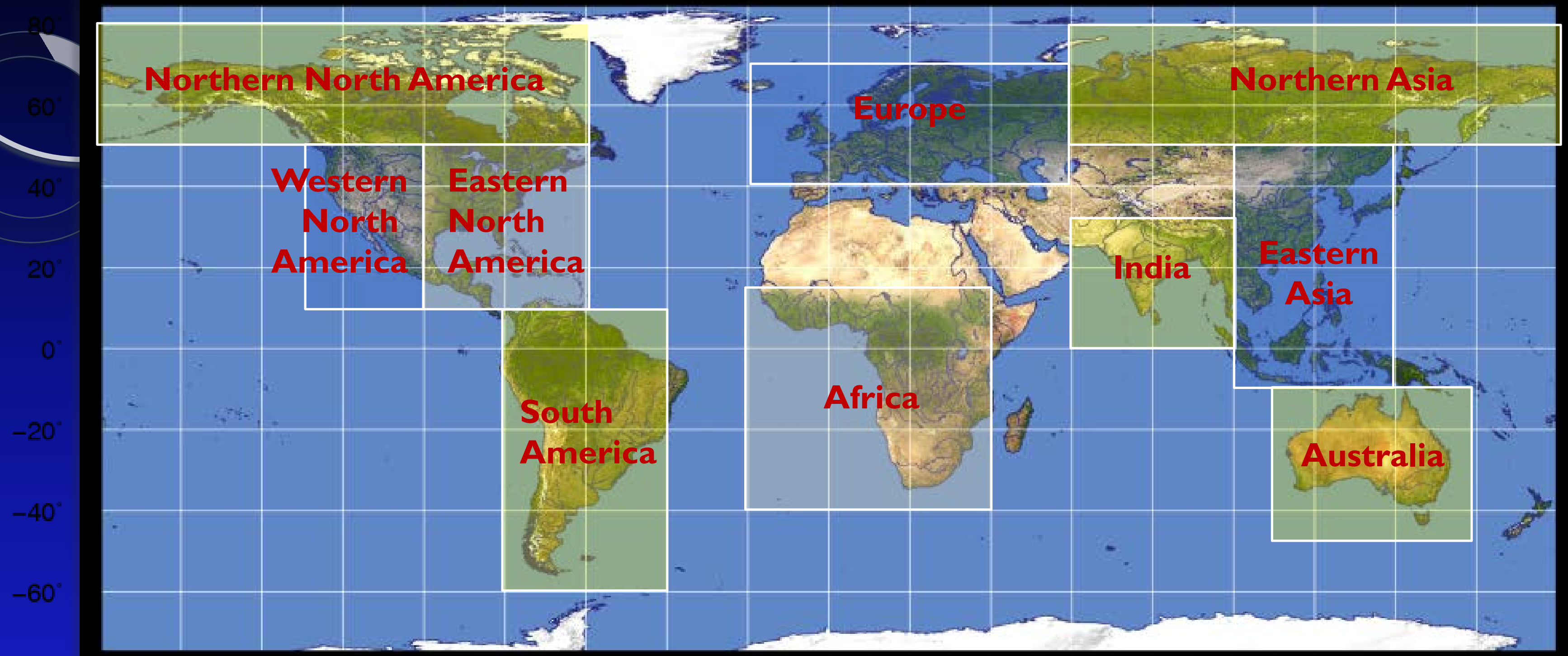
New M5->M11 Relationship



New M5->M11 Relationship
Average of best two solutions



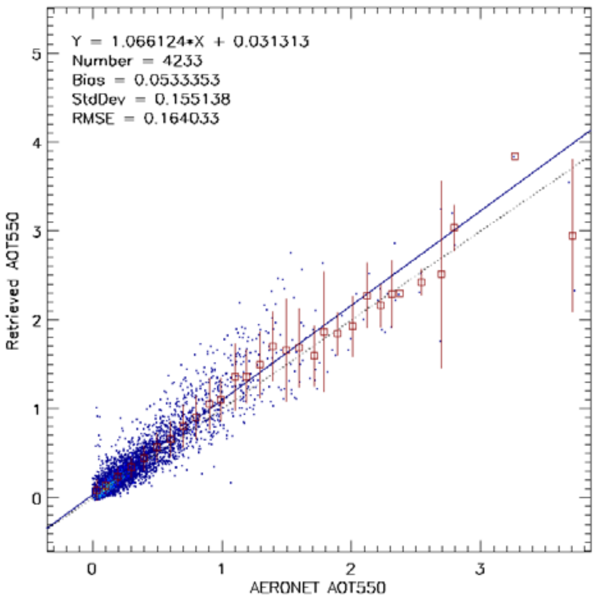
Regional Evaluation



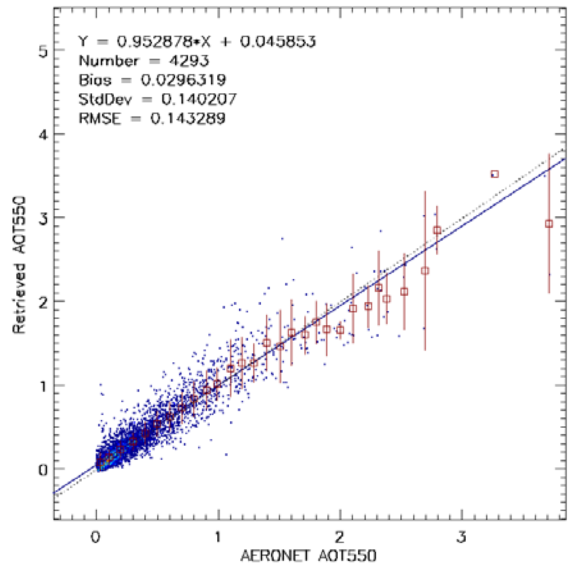
Domain	Longitude	Latitude
Northern North America	180° W - 60° W	50° N - 80° N
Northern Asia	60° E - 180° E	50° N - 80° N
Europe	20° W - 60° E	40° N - 70° N
Western North America	130° W - 100° W	10° N - 50° N
Eastern North America	100° W - 60° W	10° N - 50° N
South America	80° W - 40° W	60° S - 10° N
South Africa	20° W - 40° E	40° S - 15° N
India	60° E - 100° E	0° - 30° N
Eastern Asia	100° E - 140° E	10° S - 50° N
Australia	110° E - 160° E	50° S - 10° S

Eastern Asia

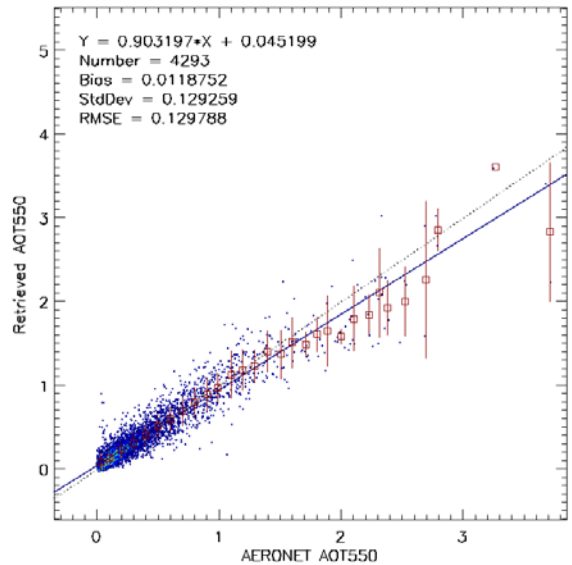
EPS Original Retrieval



New M5->M11 Relationship

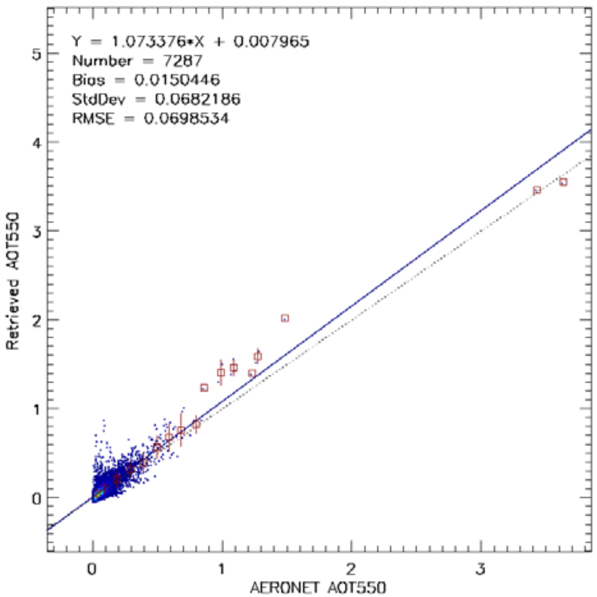


New M5->M11 Relationship
Average of best two solutions

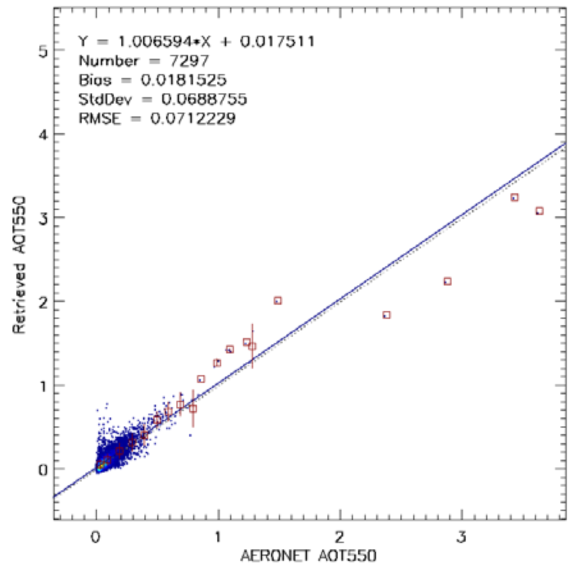


- Eastern North America

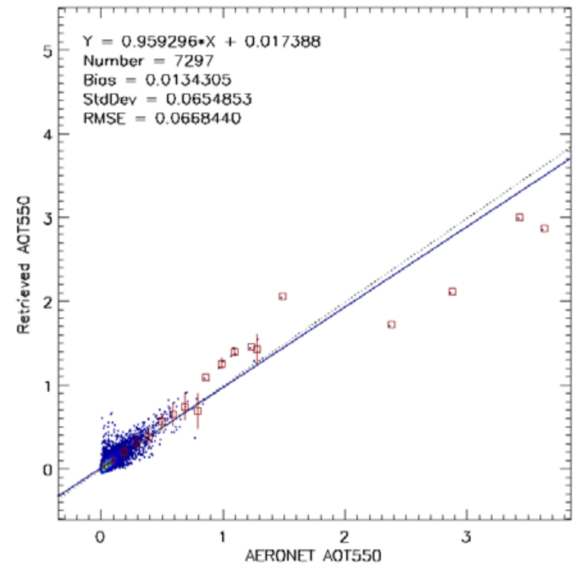
EPS Original Retrieval



New M5->M11 Relationship

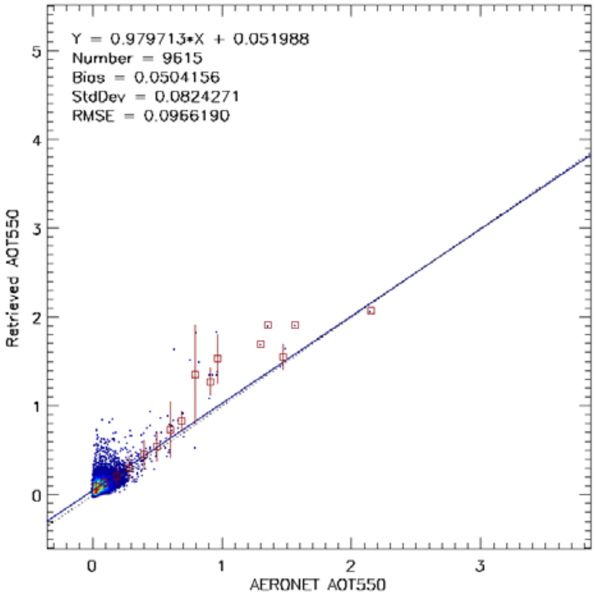


New M5->M11 Relationship
Average of best two solutions

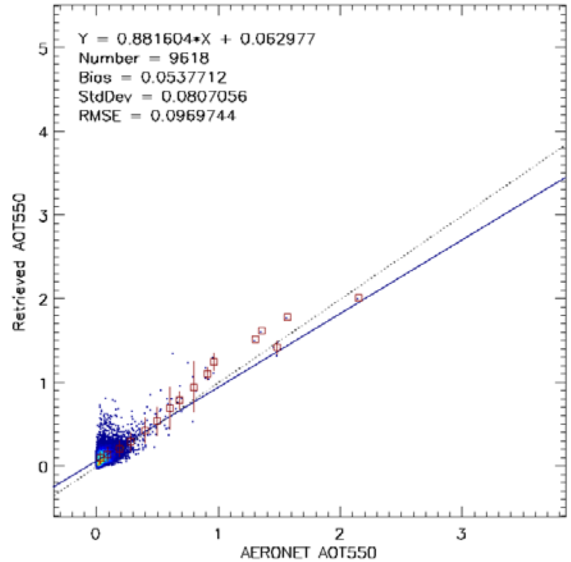


• Western North America

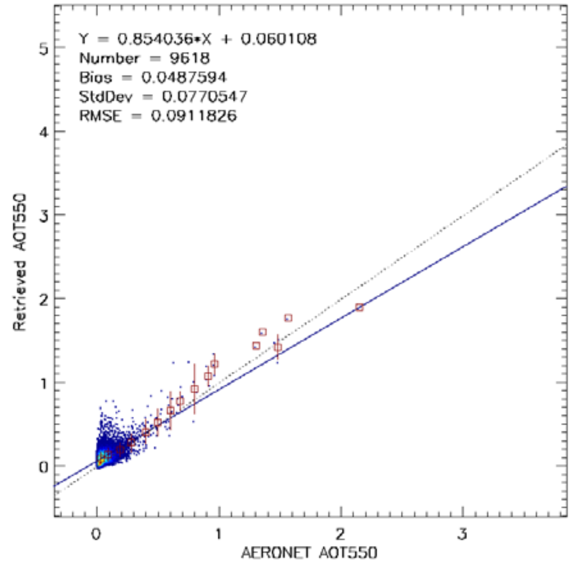
EPS Original Retrieval



New M5->M11 Relationship

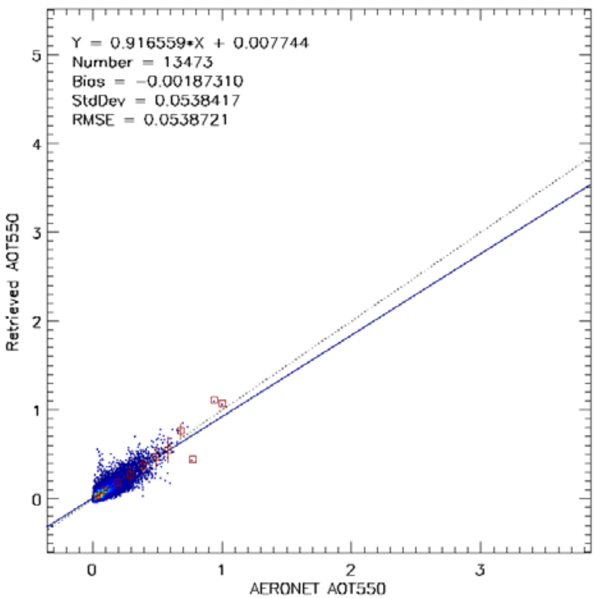


New M5->M11 Relationship
Average of best two solutions

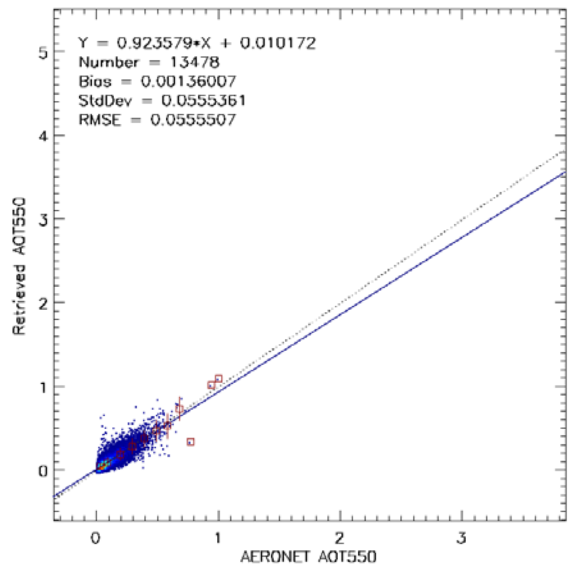


Europe

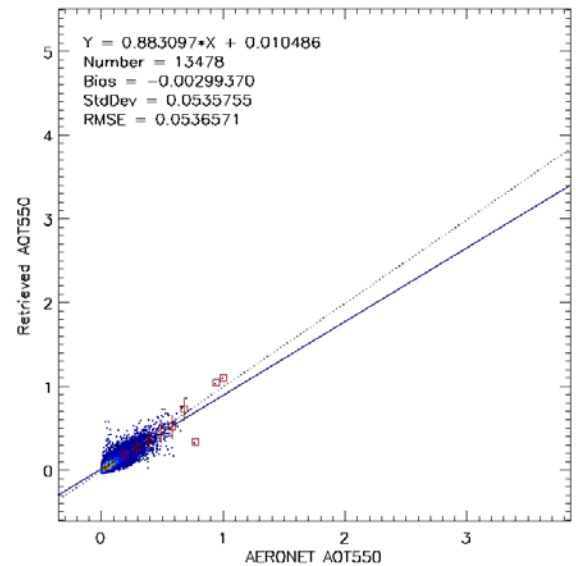
EPS Original Retrieval



New M5->M11 Relationship

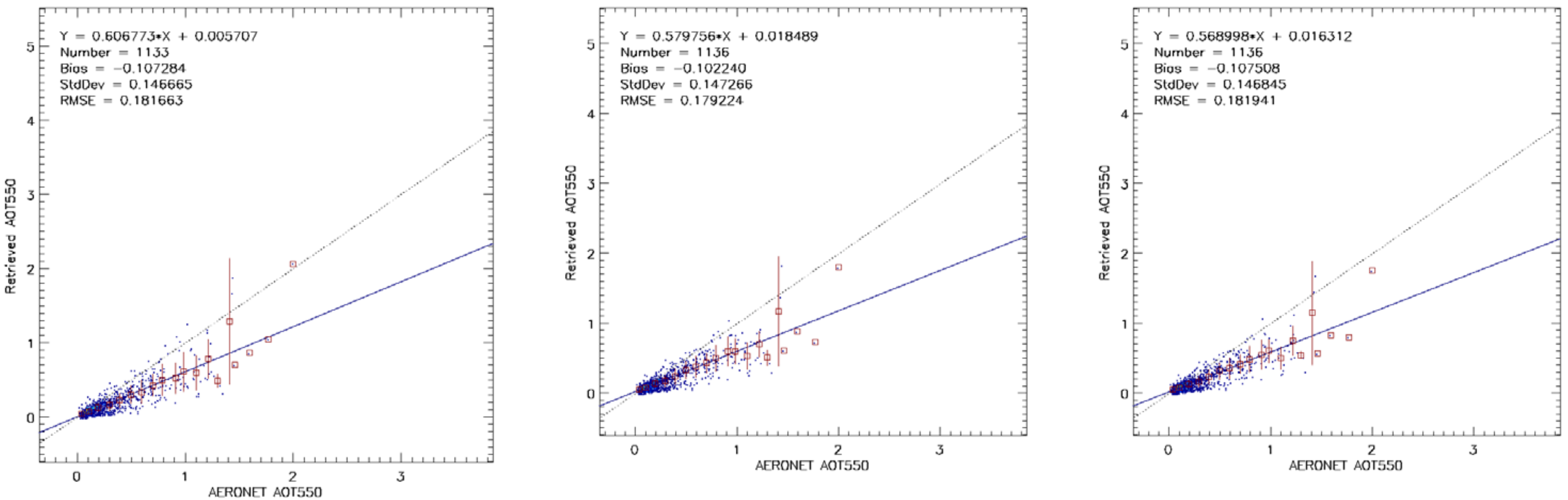


New M5->M11 Relationship
Average of best two solutions

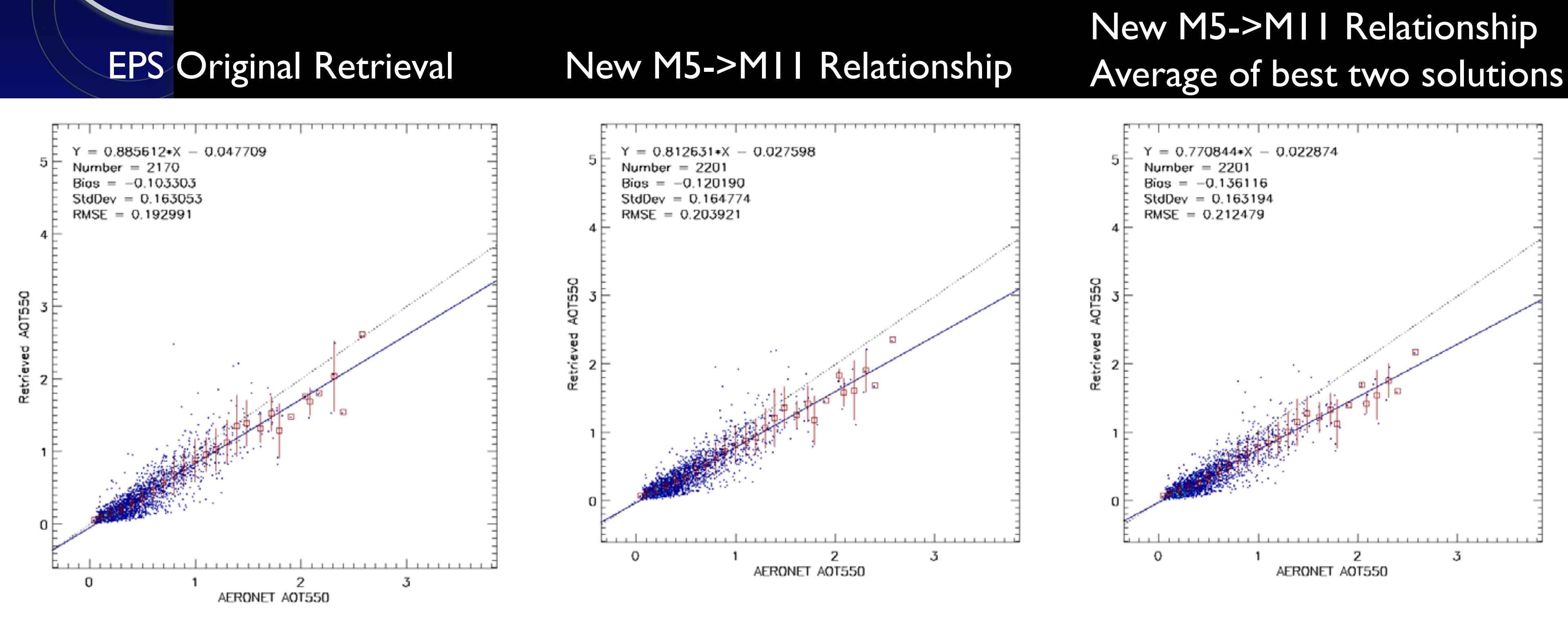


• Africa

EPS Original Retrieval | New M5->M11 Relationship | New M5->M11 Relationship Average of best two solutions

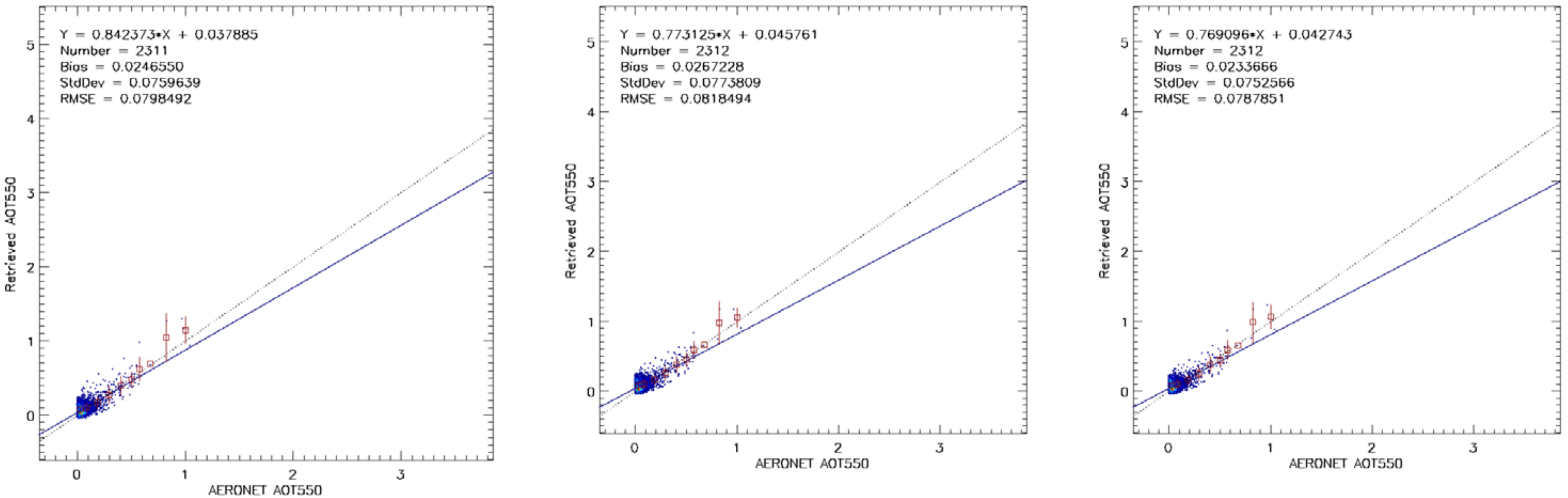


• India


EPS Original Retrieval
New M5->M11 Relationship
New M5->M11 Relationship
Average of best two solutions
Y = 0.885612*X − 0.047709
Number = 2170
Bias = −0.103303
StdDev = 0.163053
RMSE = 0.192991
Y = 0.812631*X − 0.027598
Number = 2201
Bias = −0.120190
StdDev = 0.164774
RMSE = 0.203921
Y = 0.770844*X − 0.022874
Number = 2201
Bias = −0.136116
StdDev = 0.163194
RMSE = 0.212479
Retrieved AOT550
AERONET AOT550

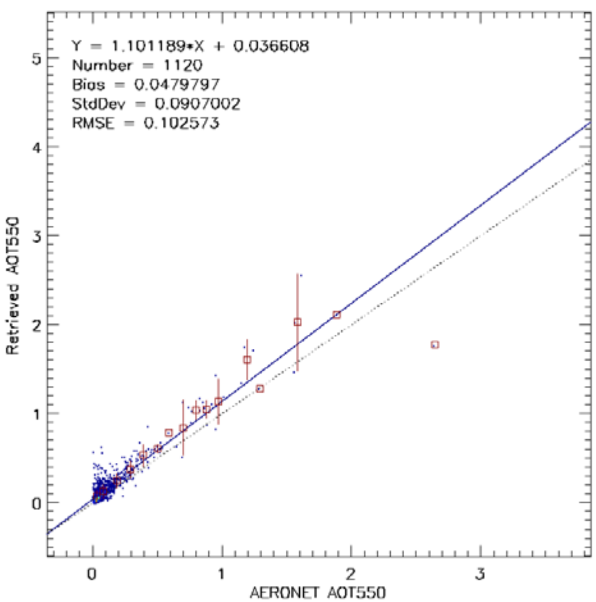
South America

EPS Original Retrieval | New M5->M11 Relationship | New M5->M11 Relationship Average of best two solutions

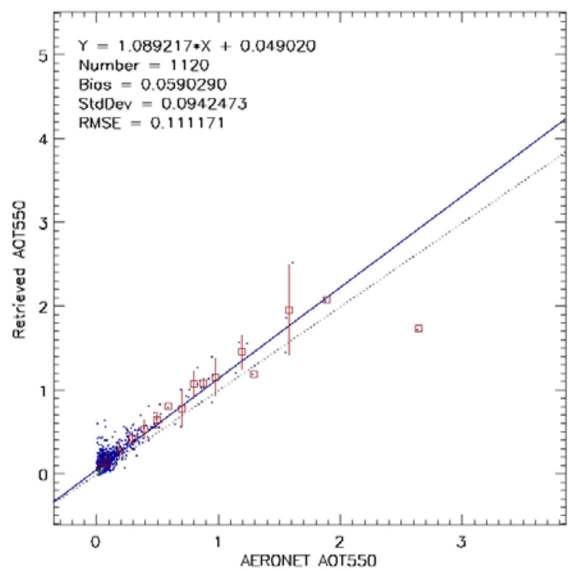


Northern North America

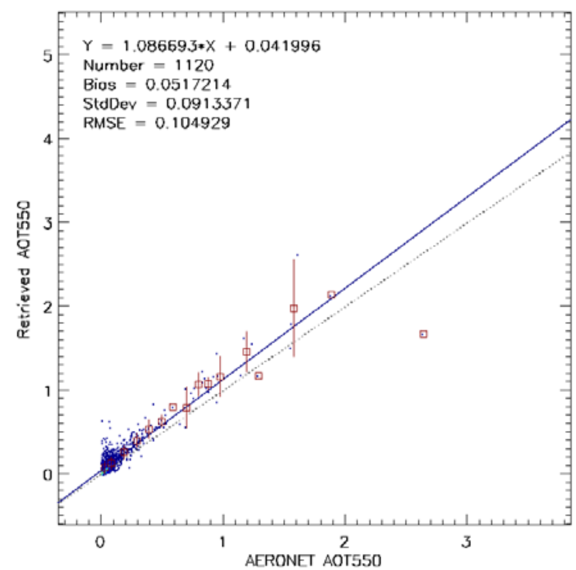
EPS Original Retrieval



New M5->M11 Relationship

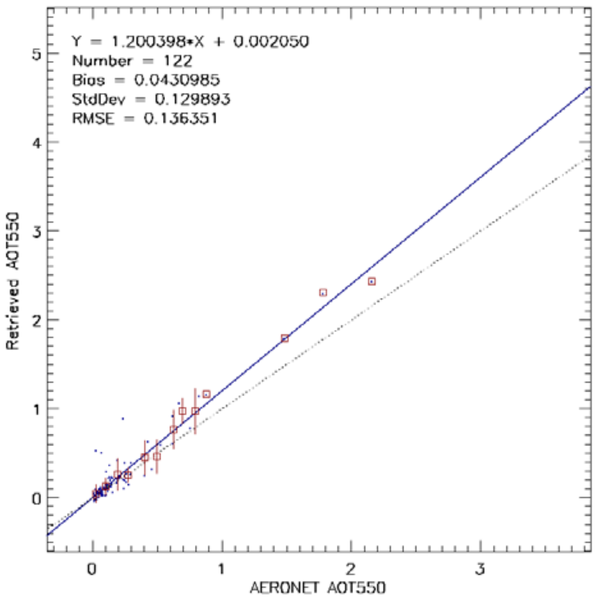


New M5->M11 Relationship
Average of best two solutions

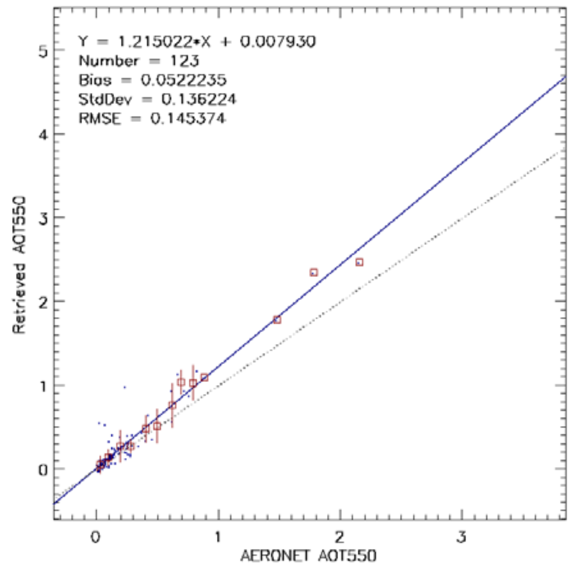


• Northern Asia

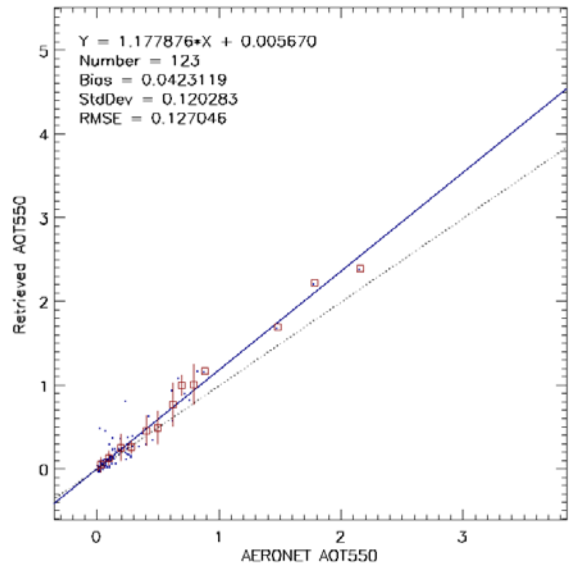
EPS Original Retrieval



New M5->M11 Relationship

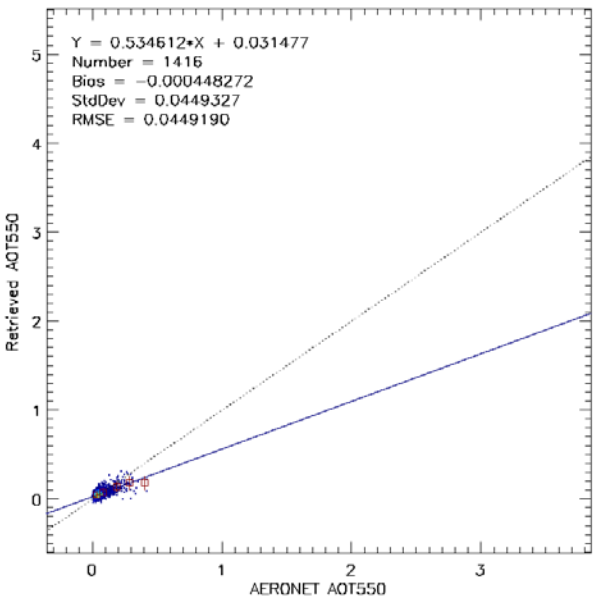


New M5->M11 Relationship
Average of best two solutions

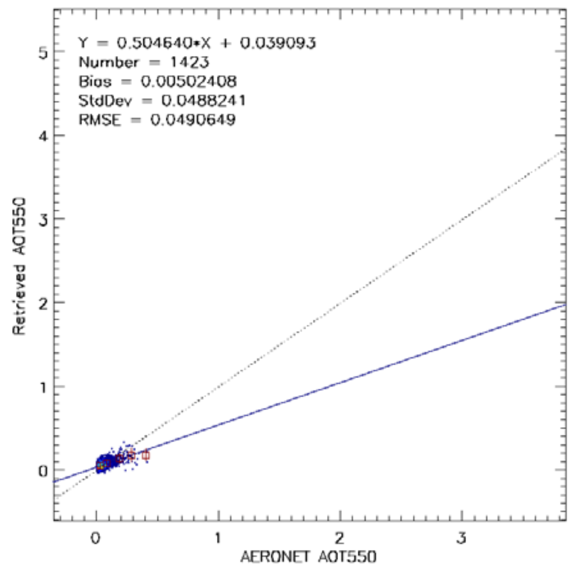


Australia

EPS Original Retrieval



New M5->M11 Relationship



New M5->M11 Relationship
Average of best two solutions