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Can we improve satellite retrievals of Ångström exponent over land?

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Ångström Exponent (AE) & AOD retrievals over land with current algorithms

Aerosol products

MODIS

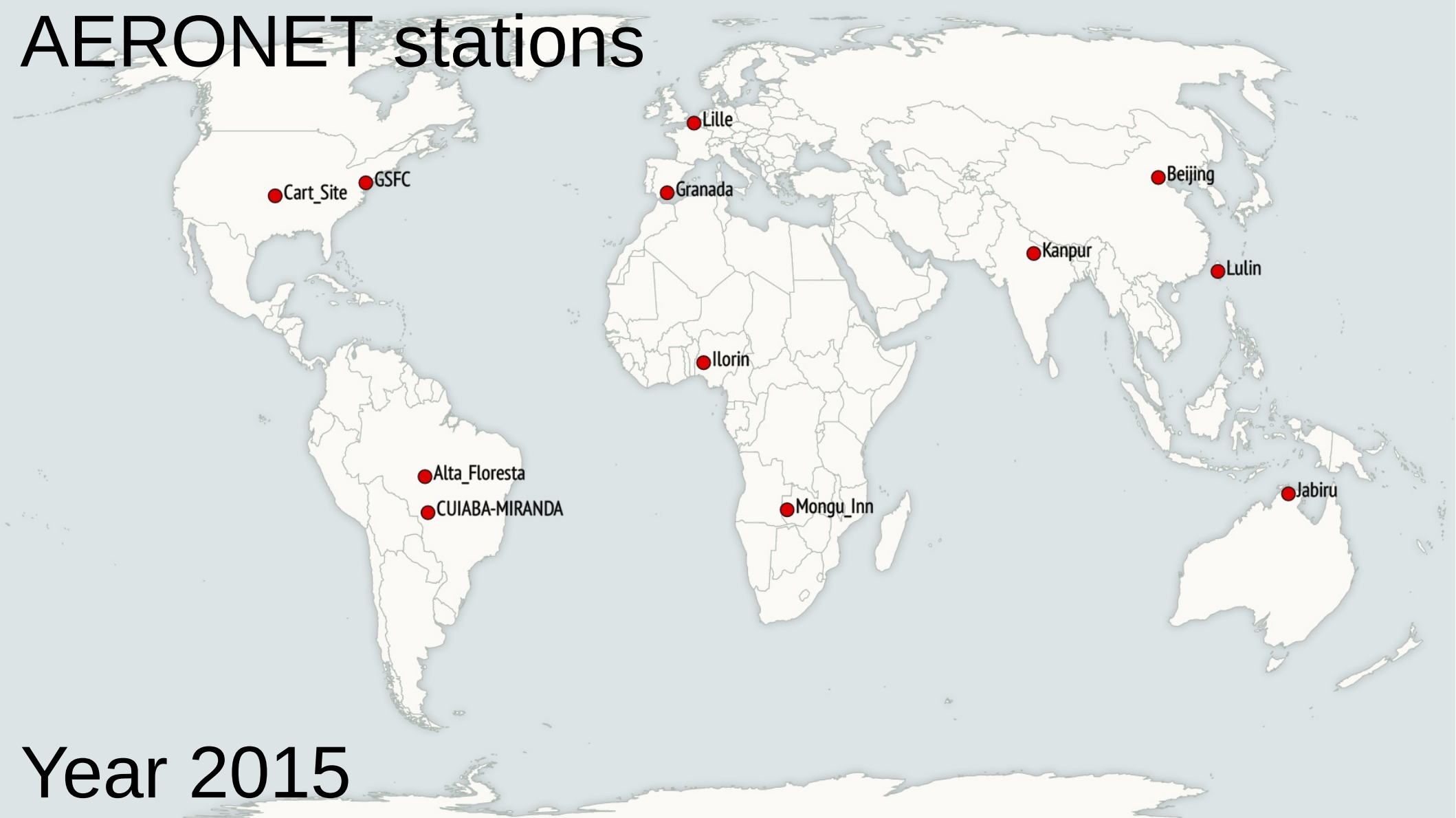
Dark Target over land C6.1 (MOD04_L2 & MYD04_L2)
Deep Blue C6.1 (MOD04_L2 & MYD04_L2)
MAIAC C6 (MCD19A2)
Bayesian Aerosol Retrieval BAR (version 1.0, Aqua & Terra)

MISR

MISR Level 2 Aerosol (MIL2ASAE, F13_0023)

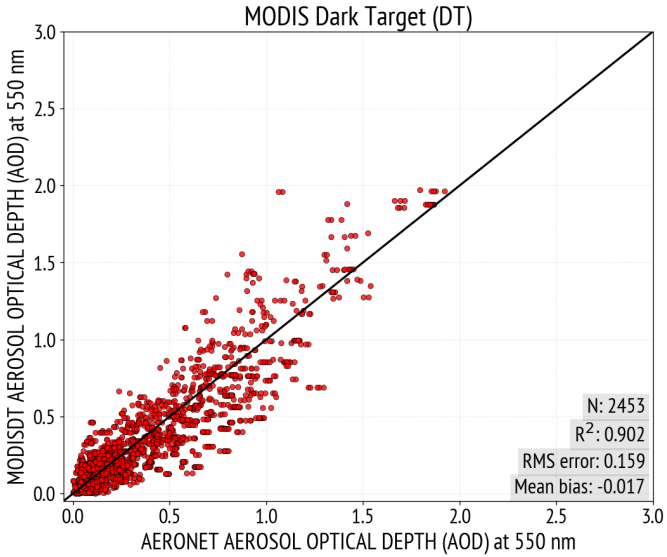
AERONET version 3, level 2.0

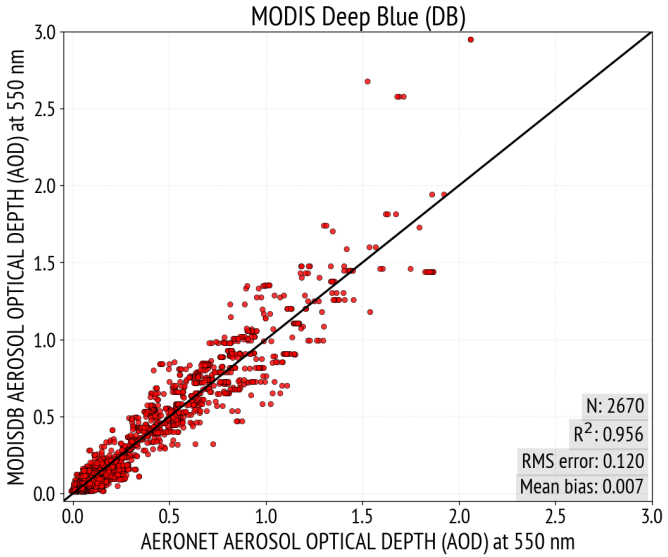
AERONET stations

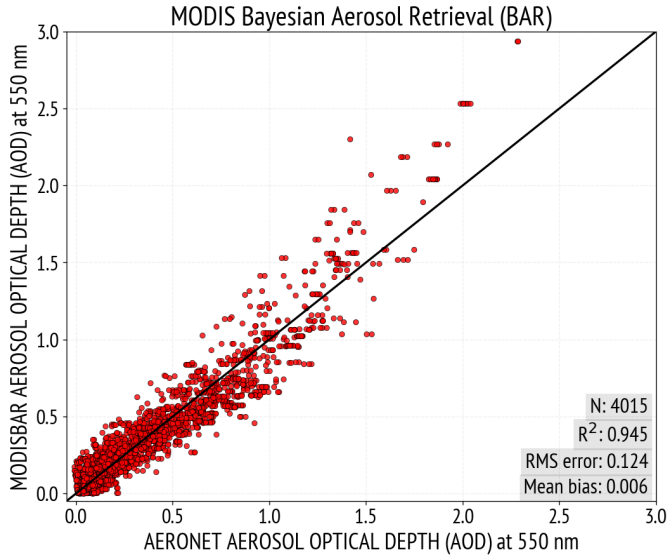


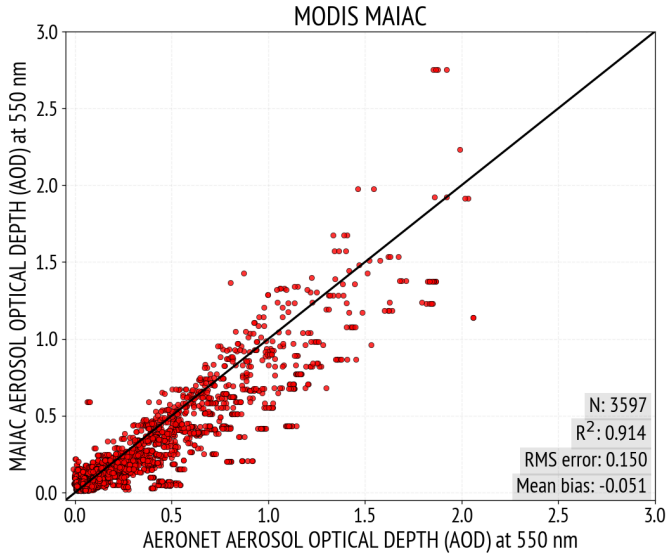
Year 2015

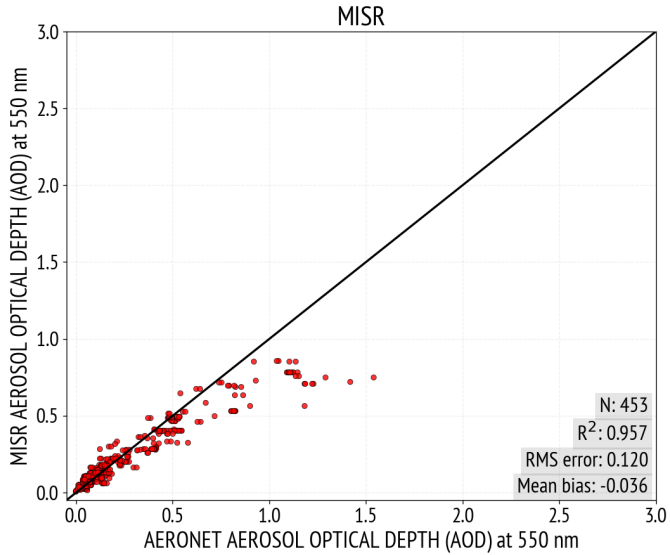
AOD

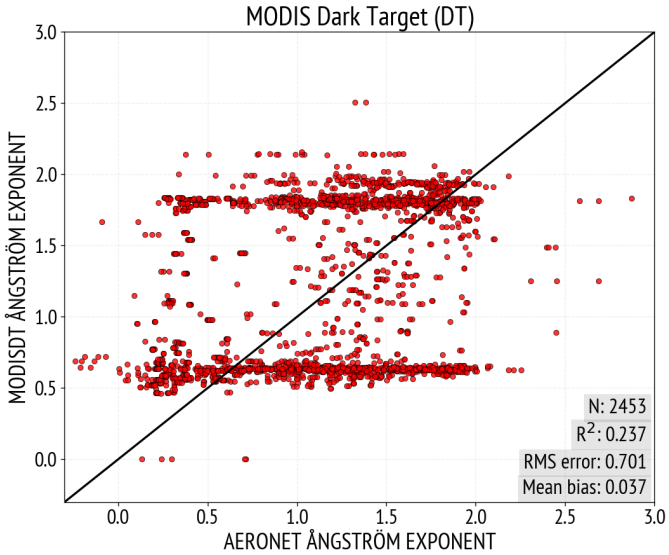

MODIS Dark Target (DT)
MODISDT AEROSOL OPTICAL DEPTH (AOD) at 550 nm
AERONET AEROSOL OPTICAL DEPTH (AOD) at 550 nm
N: 2453
R2: 0.902
RMS error: 0.159
Mean bias: -0.017

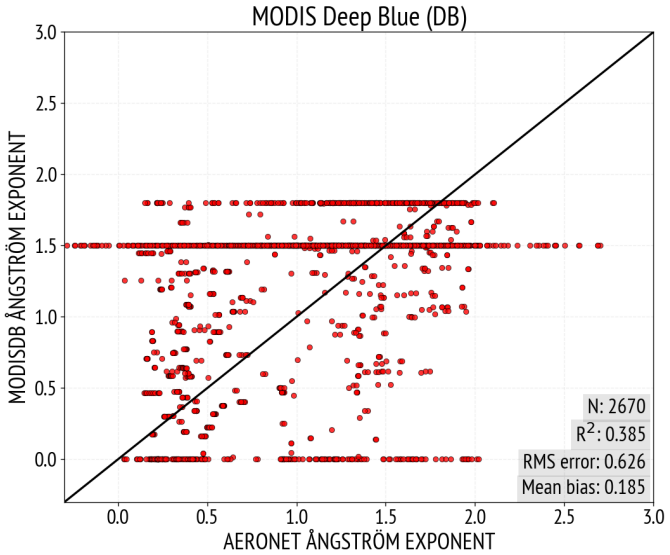

MODIS Deep Blue (DB)
MODISDB AEROSOL OPTICAL DEPTH (AOD) at 550 nm
AERONET AEROSOL OPTICAL DEPTH (AOD) at 550 nm
N: 2670
R2: 0.956
RMS error: 0.120
Mean bias: 0.007

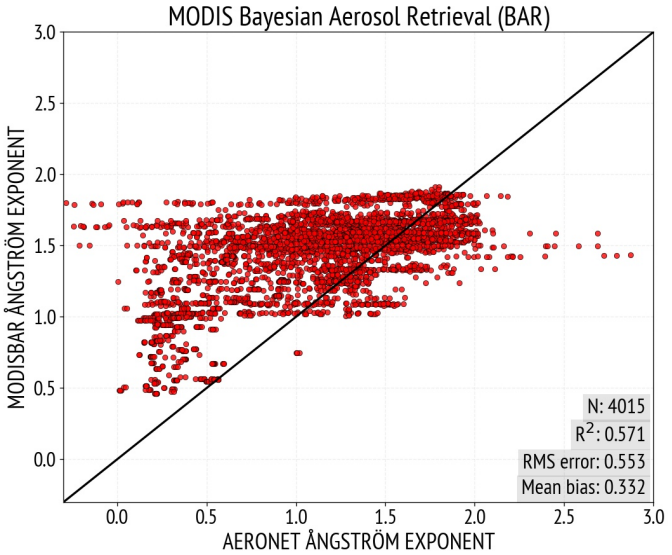

MODIS Bayesian Aerosol Retrieval (BAR)
MODISBAR AEROSOL OPTICAL DEPTH (AOD) at 550 nm
AERONET AEROSOL OPTICAL DEPTH (AOD) at 550 nm
N: 4015
R2: 0.945
RMS error: 0.124
Mean bias: 0.006

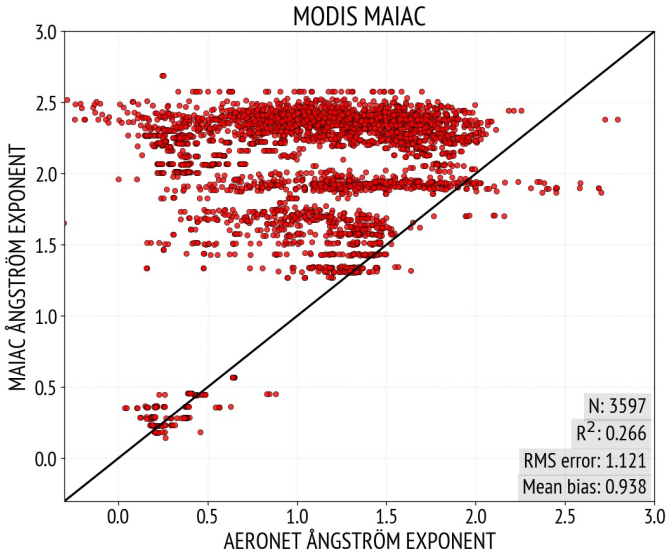

MODIS MAIAC
MAIAC AEROSOL OPTICAL DEPTH (AOD) at 550 nm
AERONET AEROSOL OPTICAL DEPTH (AOD) at 550 nm
N: 3597
R2: 0.914
RMS error: 0.150
Mean bias: -0.051

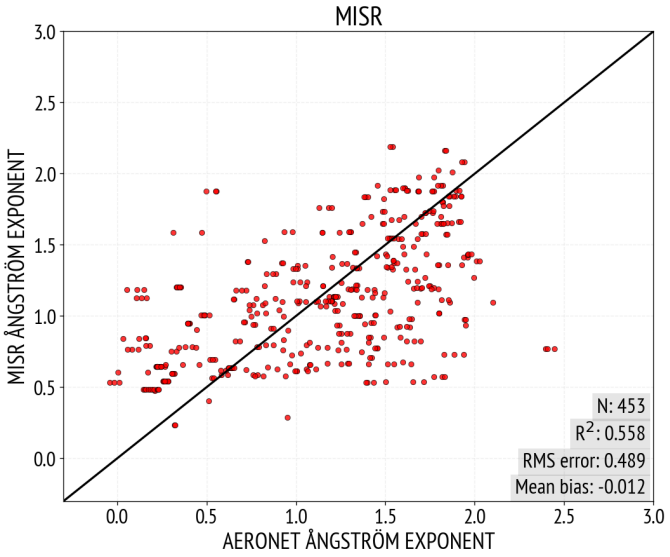

MISR
MISR AEROSOL OPTICAL DEPTH (AOD) at 550 nm
AERONET AEROSOL OPTICAL DEPTH (AOD) at 550 nm
N: 453
R2: 0.957
RMS error: 0.120
Mean bias: -0.036





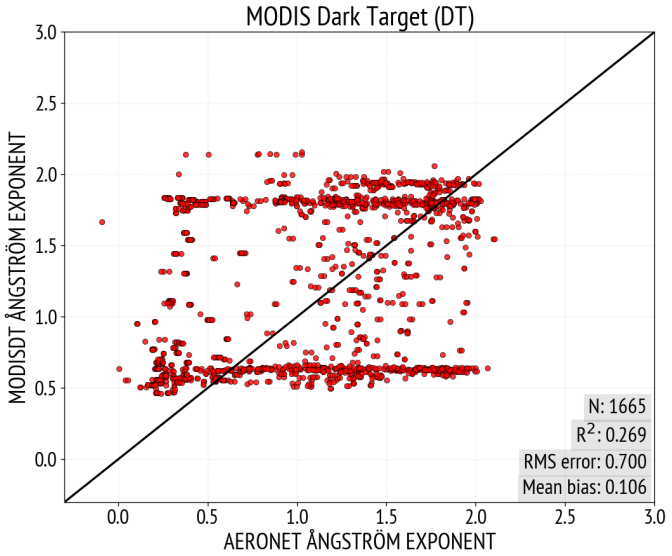


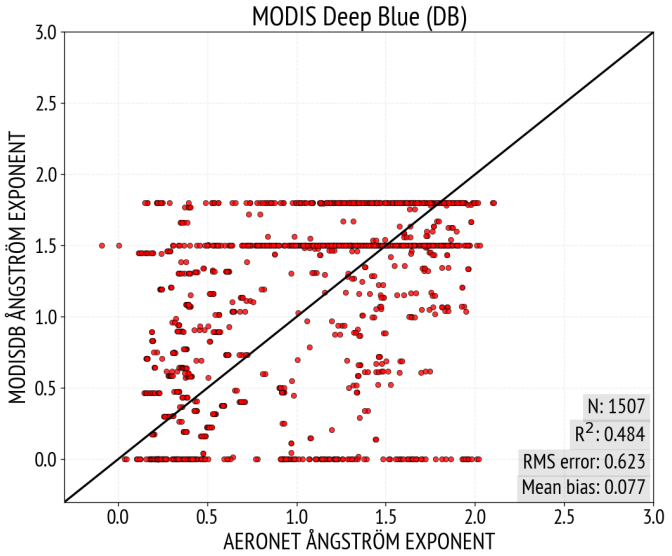


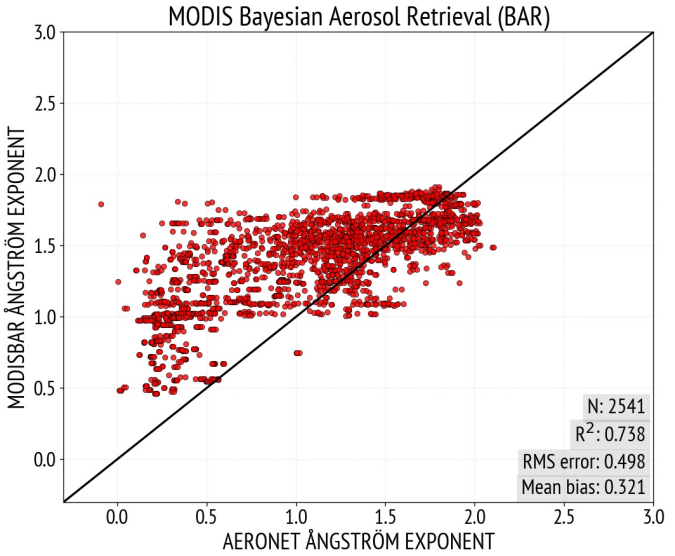


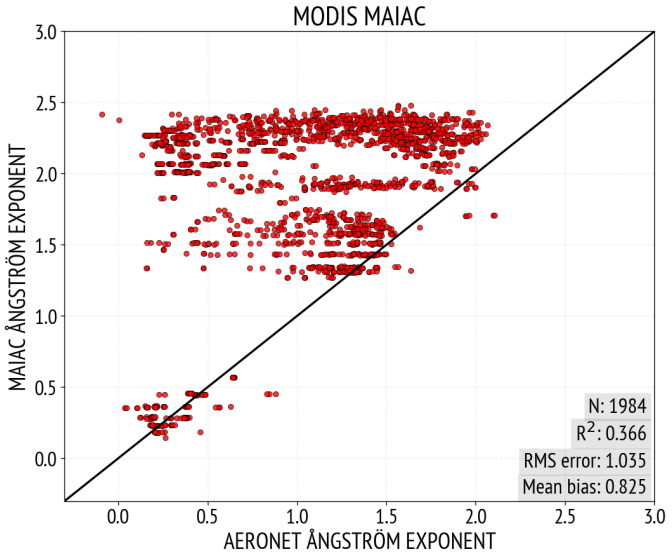
AE

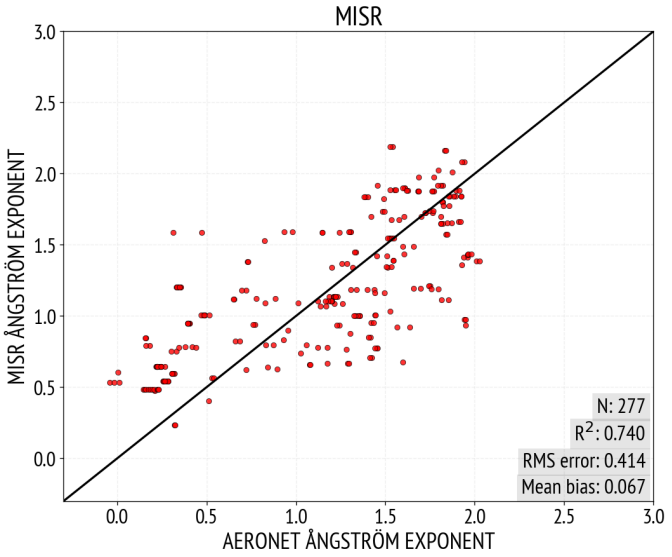
AERONET All AODs





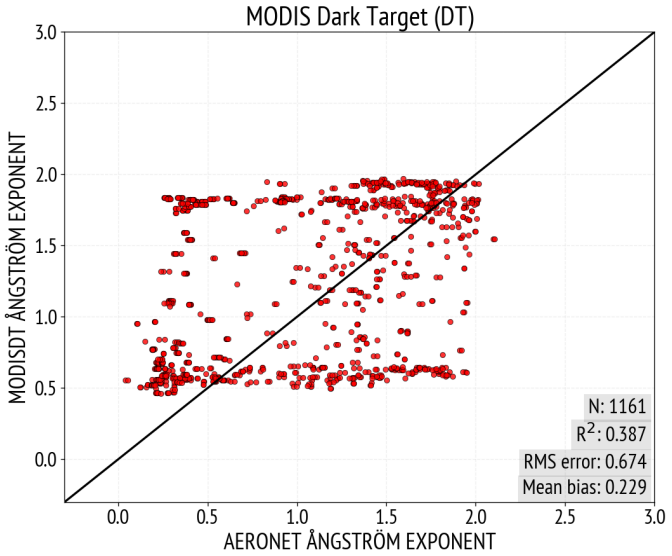


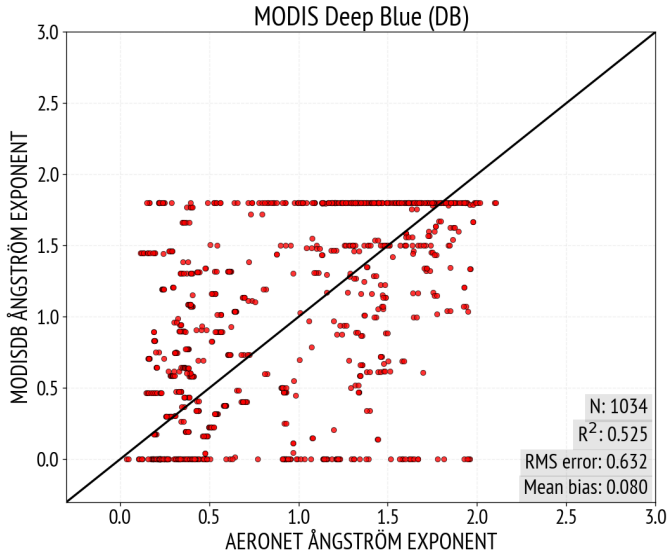


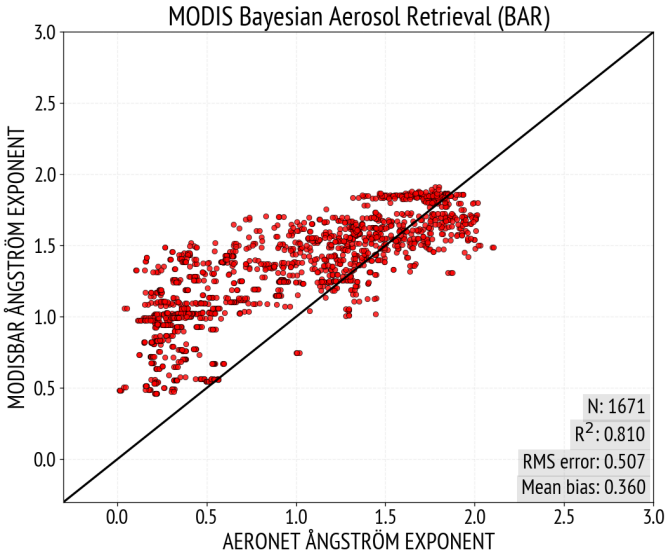


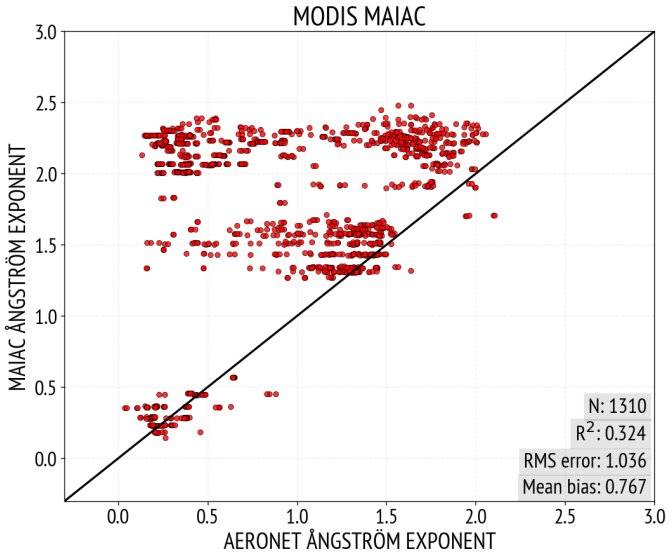
AE

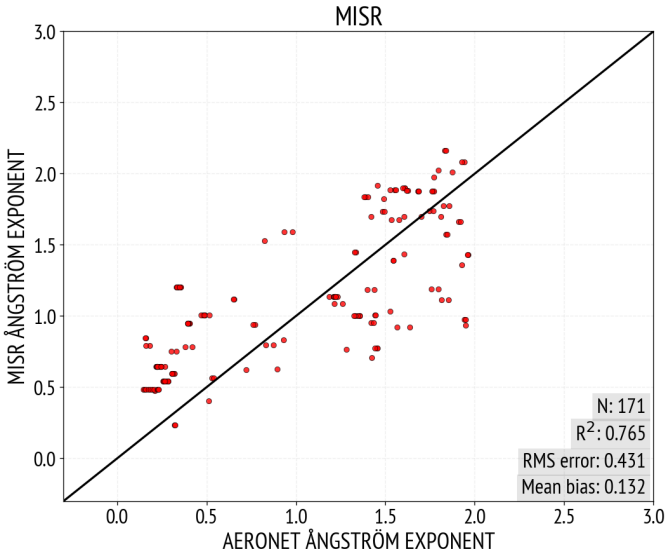
AERONET AOD >0.1





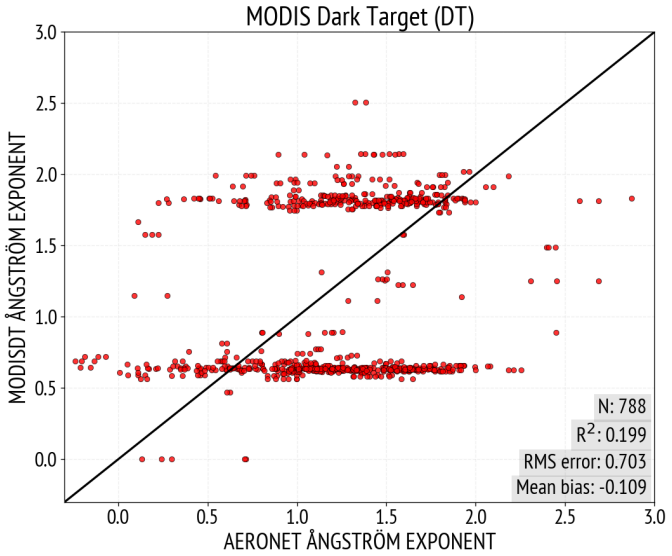


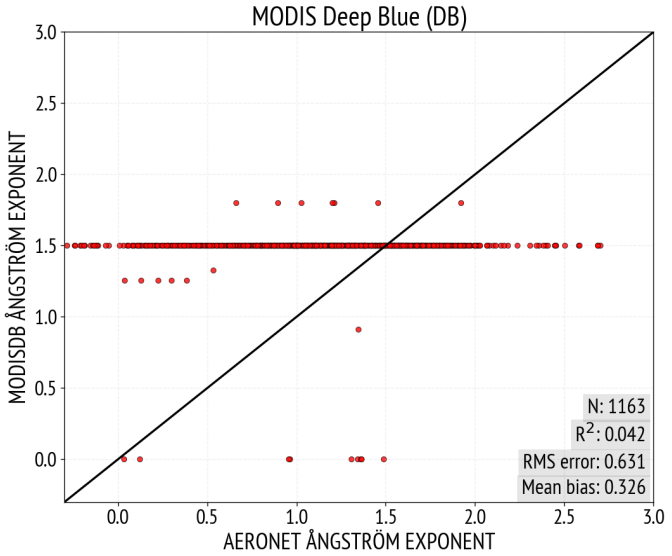


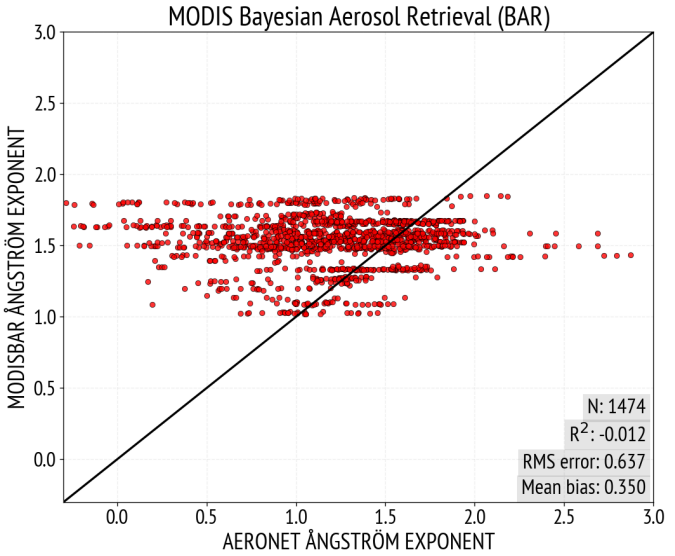


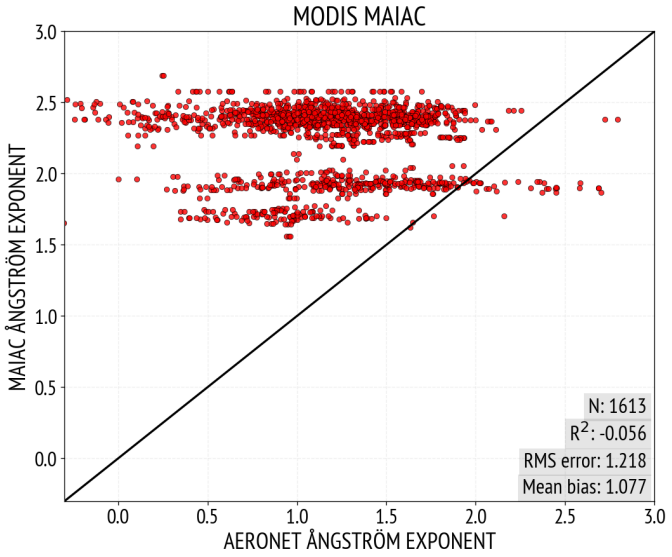
AE

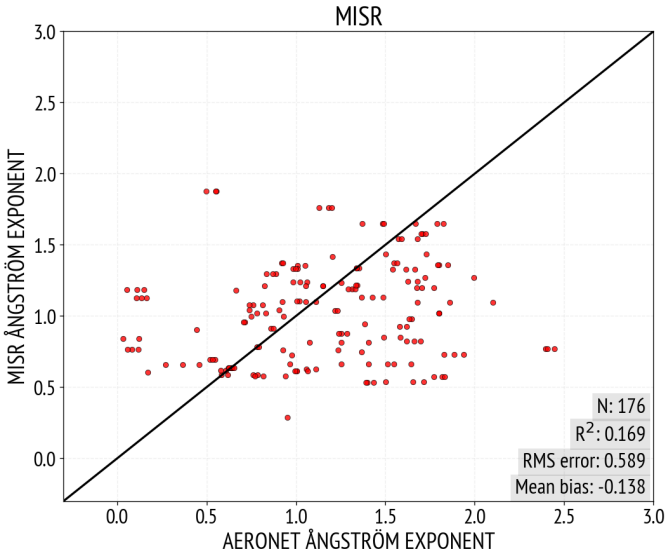
AERONET AOD >0.2









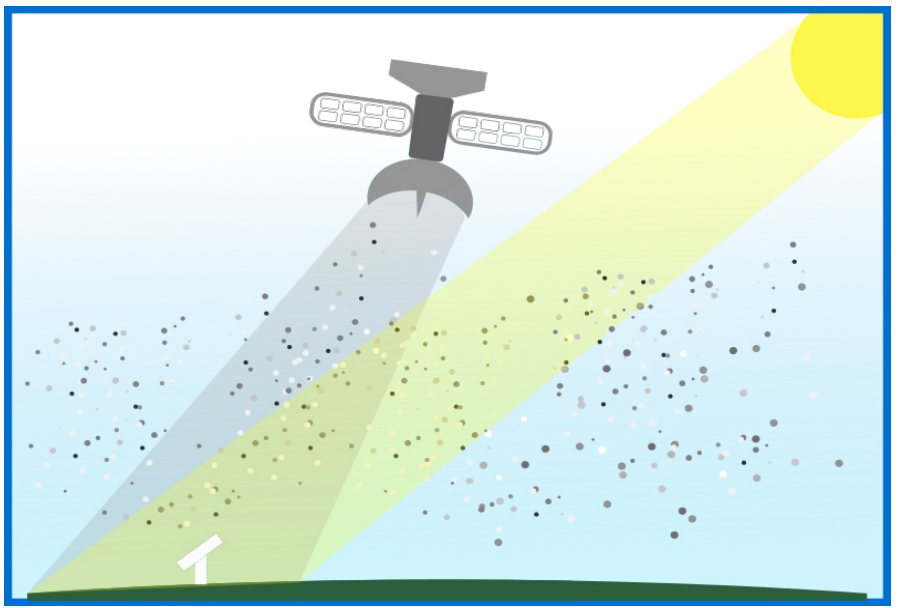


AE

AERONET AOD <0.1

Do retrieval algorithms use all the information of satellite observations?

$$AE = DT(x) + e$$



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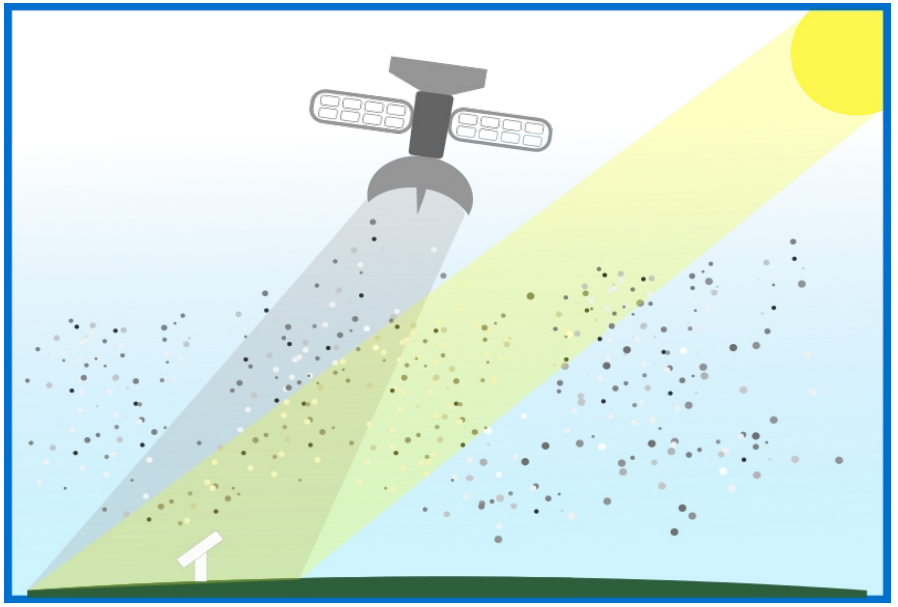
Retrieval algorithm

Satellite observations (TOA reflectance etc)

True aerosol property (AE)

$AE = DT(x) + e$

Retrieval error



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Retrieval algorithm

Satellite observations (TOA reflectance etc)

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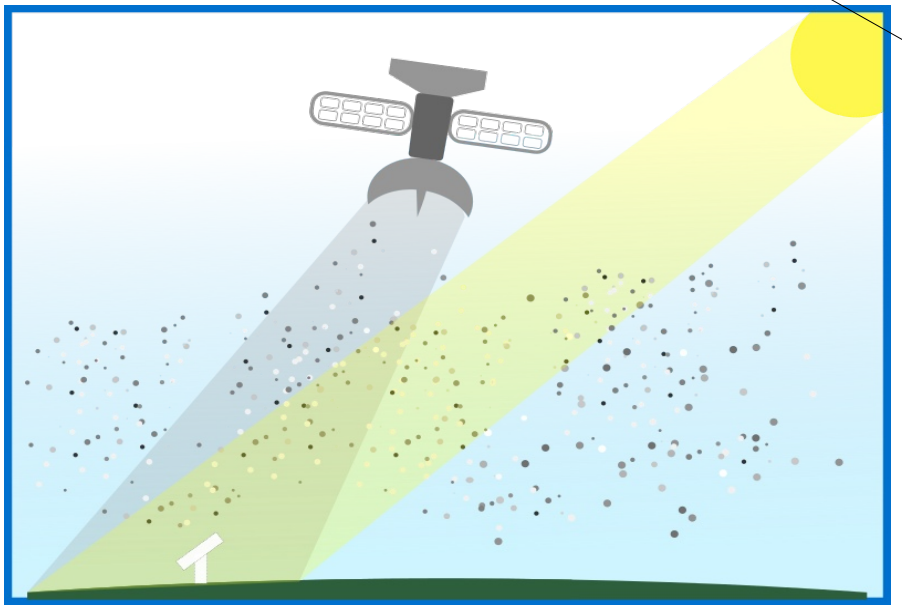


Should not depend on x

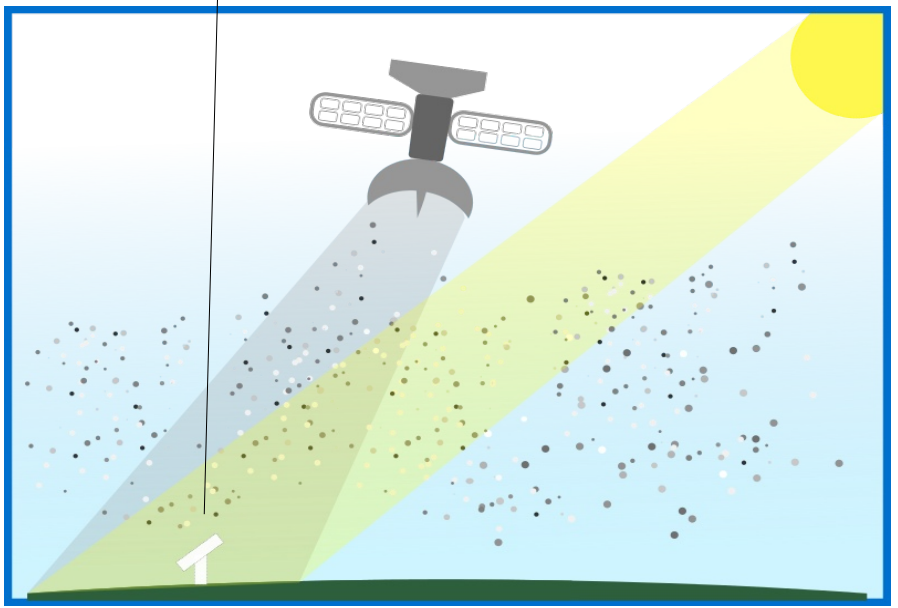
DT over land

MODIS observations (TOA reflectance etc)

AERONET AE

$$AE = DT(x) + e$$

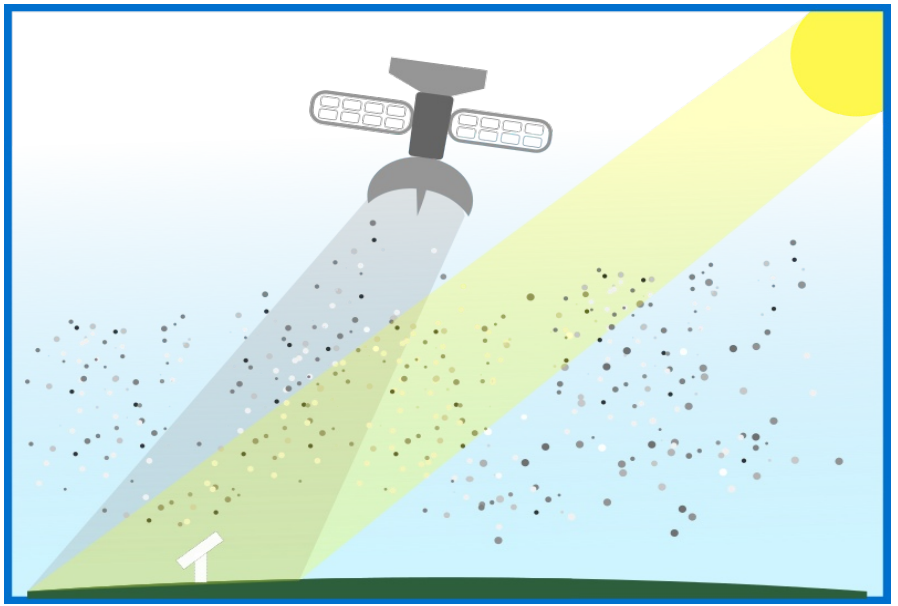
Retrieval error



AERONET AE

Dark Target over land retrieval

$$e = AE - DT(x)$$



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1. Collocate AERONET & MODIS DT over land AE

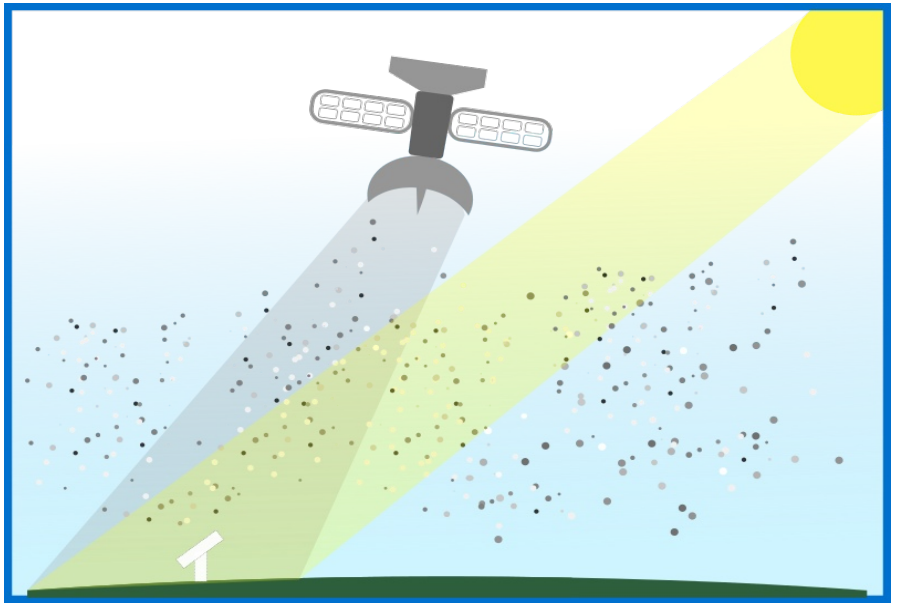
2. Compute e

3. Train a machine learning model to predict e given TOA reflectances observed by MODIS

AERONET AE

Dark Target over land retrieval

$$e = AE - DT(x)$$



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1. Collocate AERONET & MODIS DT over land AE

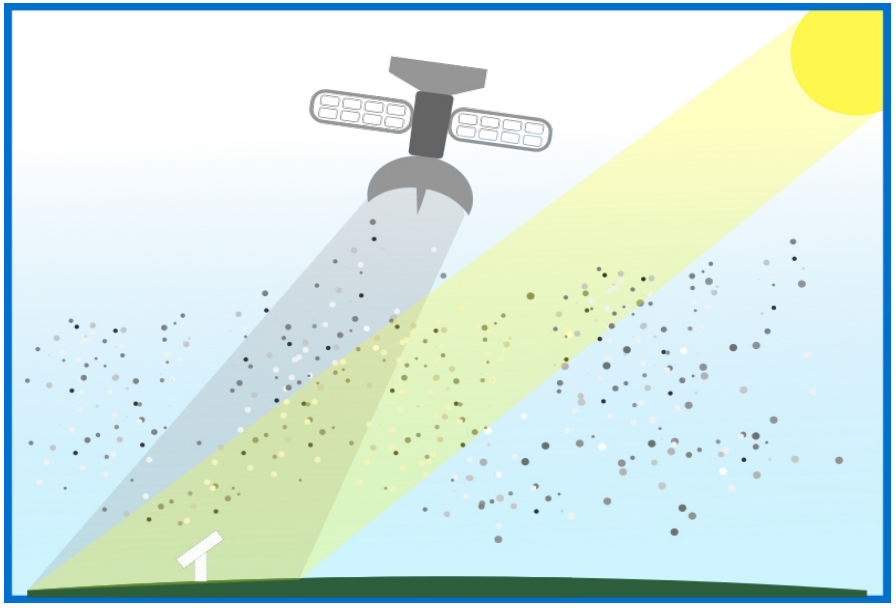
2. Compute e

3. Train a machine learning model to predict e given TOA reflectances observed by MODIS

AERONET AE

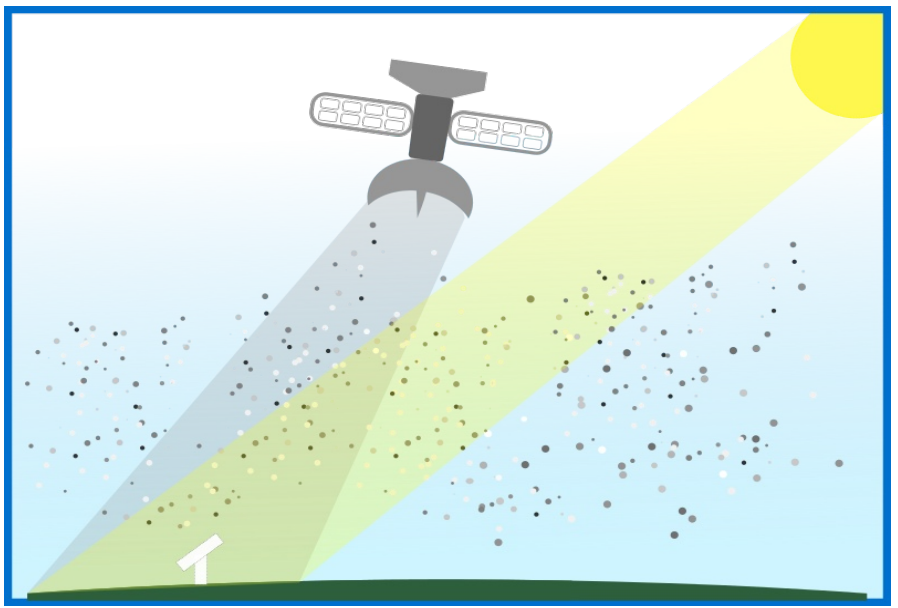
Dark Target over land retrieval

$$e = AE - DT(x) \approx CORR(x)$$



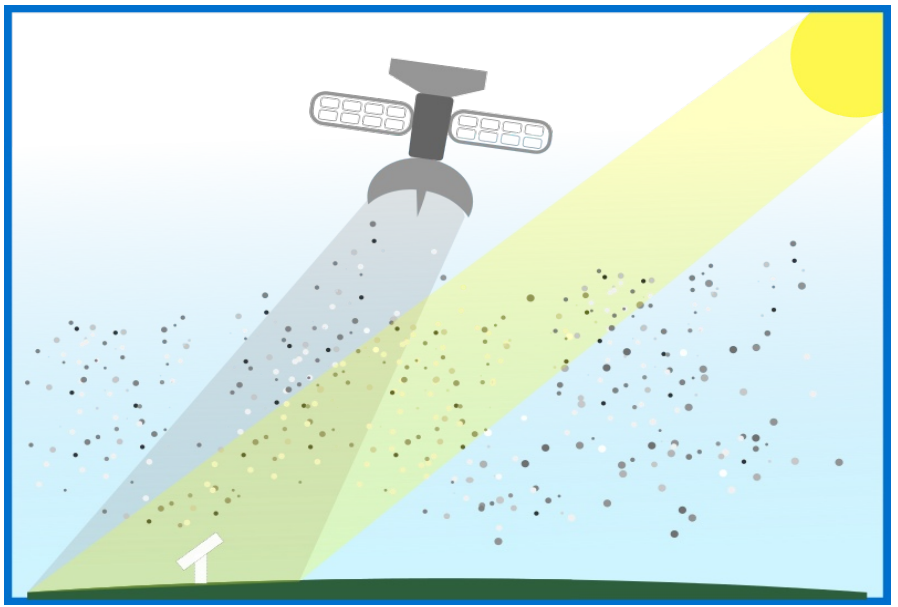
Post-process correction

$$AE \approx DT(x) + CORR(x)$$



Post-process correction

$$AE = DT(x) + CORR(x) + e$$



* We use years 2013 and 2014 for training our post-process correction model (Random Forest regression model)

* We use western hemisphere AERONET stations to train our eastern hemisphere model and vice versa

* We test our model using 2015 data

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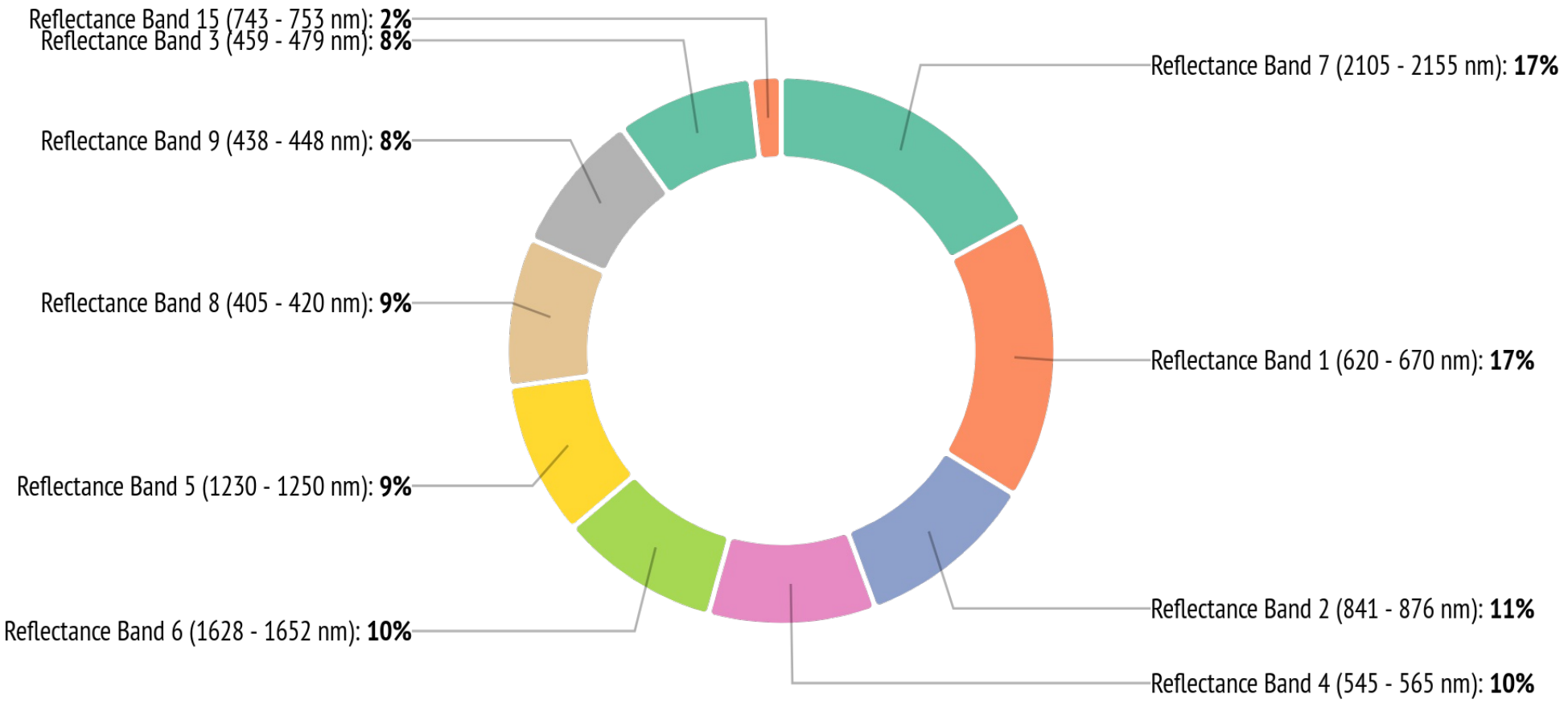
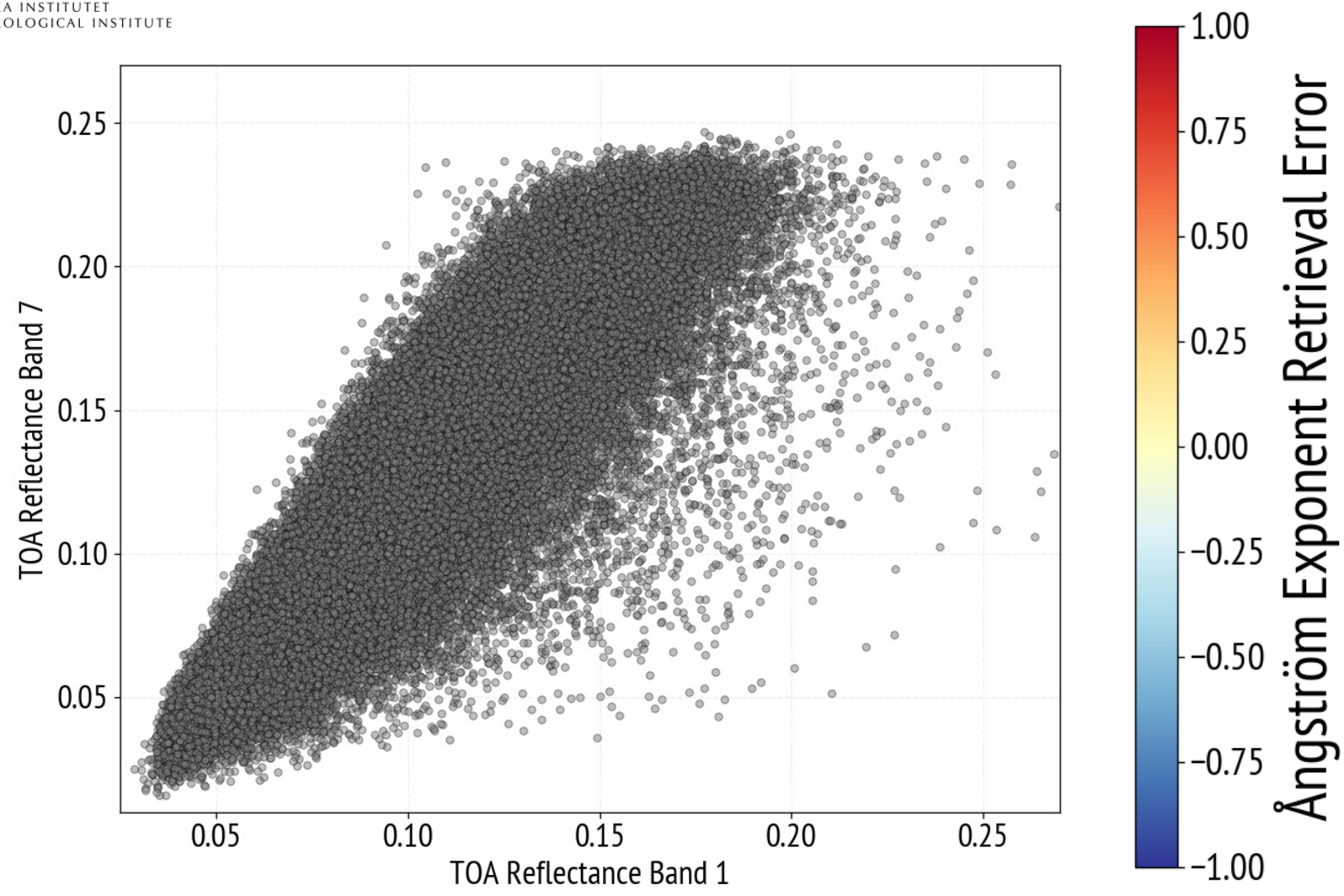
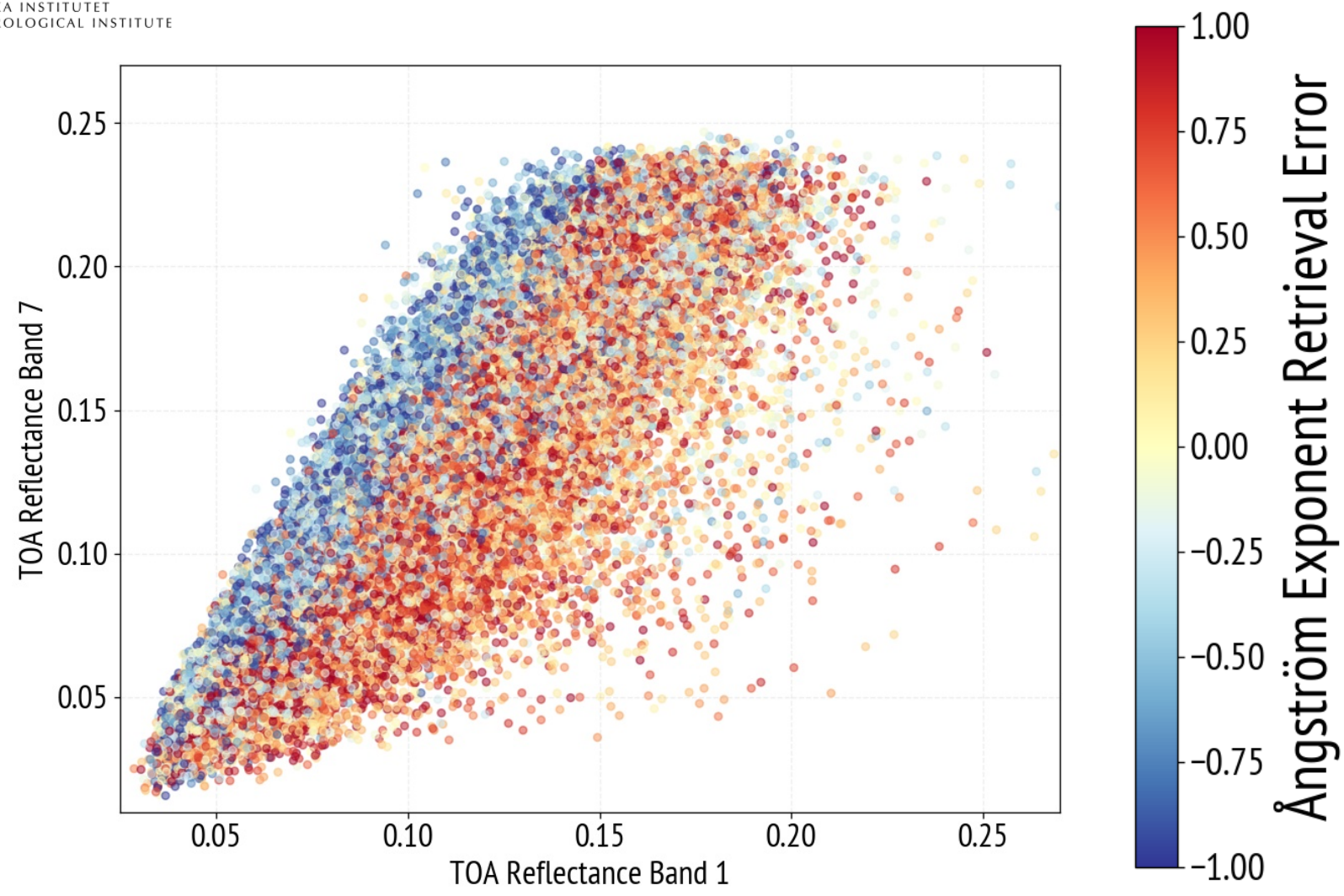
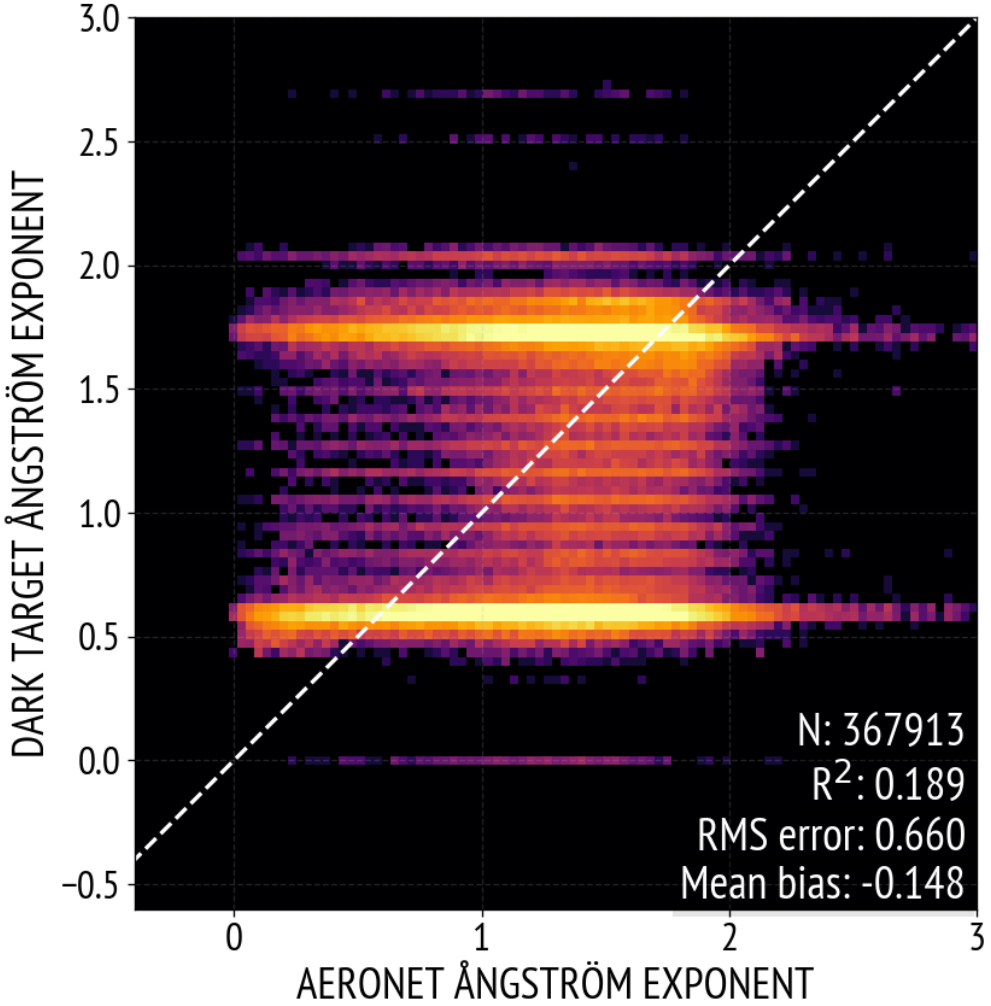
Importance of TOA reflectances in predicting e




TOA Reflectance Band 7
0.25
0.20
0.15
0.10
0.05
0.05
0.10
0.15
0.20
0.25
TOA Reflectance Band 1
Ångström Exponent Retrieval Error
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00


TOA Reflectance Band 7
0.25
0.20
0.15
0.10
0.05
0.05
0.10
0.15
0.20
0.25
TOA Reflectance Band 1
Ångström Exponent Retrieval Error
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00


DARK TARGET ÅNGSTRÖM EXPONENT
AERONET ÅNGSTRÖM EXPONENT
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
1
2
3
N: 367913
R²: 0.189
RMS error: 0.660
Mean bias: -0.148

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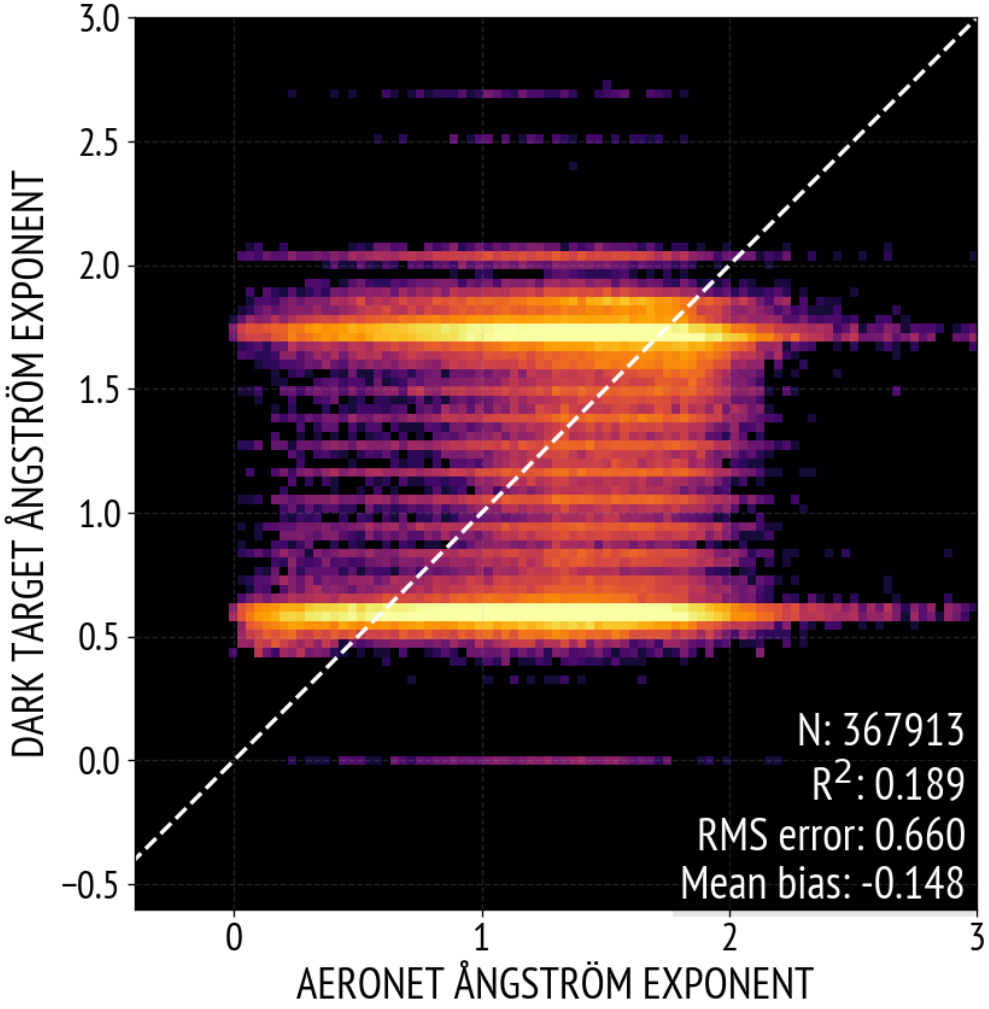
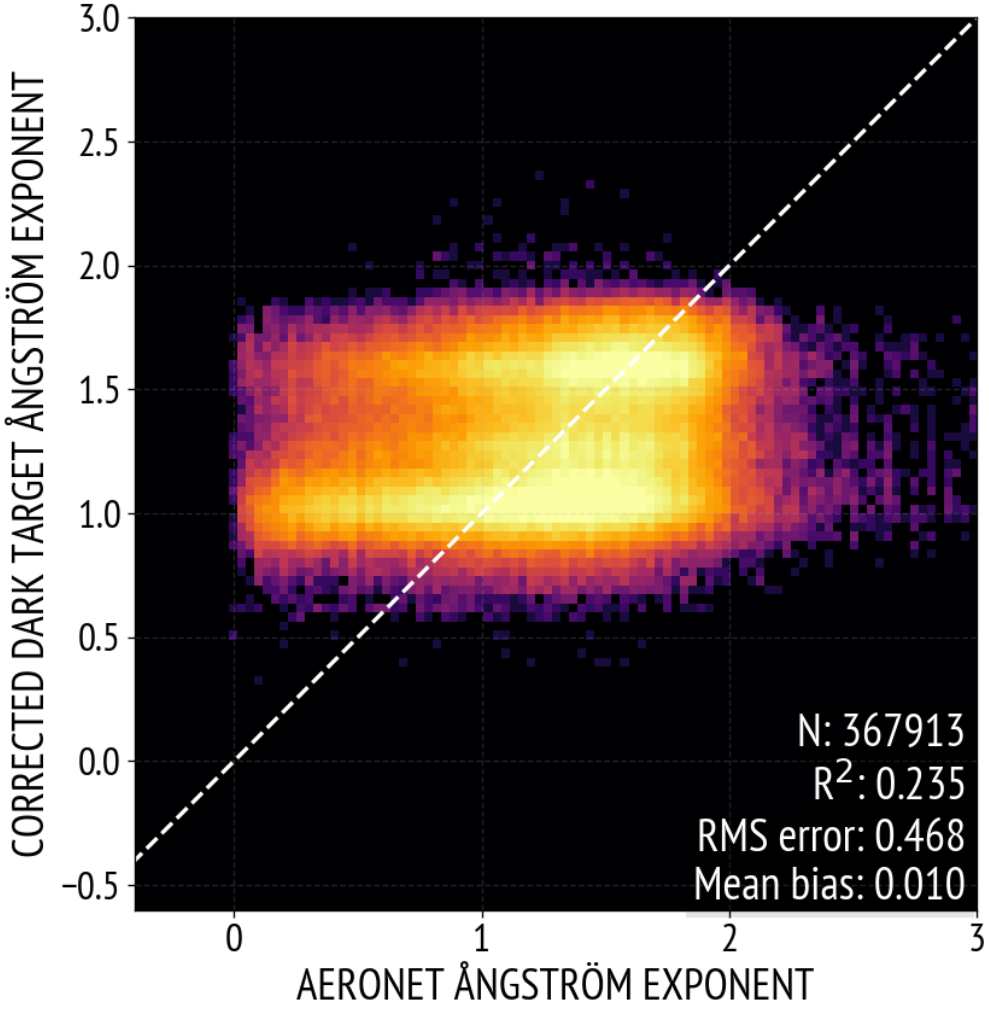
Correction with x = B01 & B07 TOA reflectances





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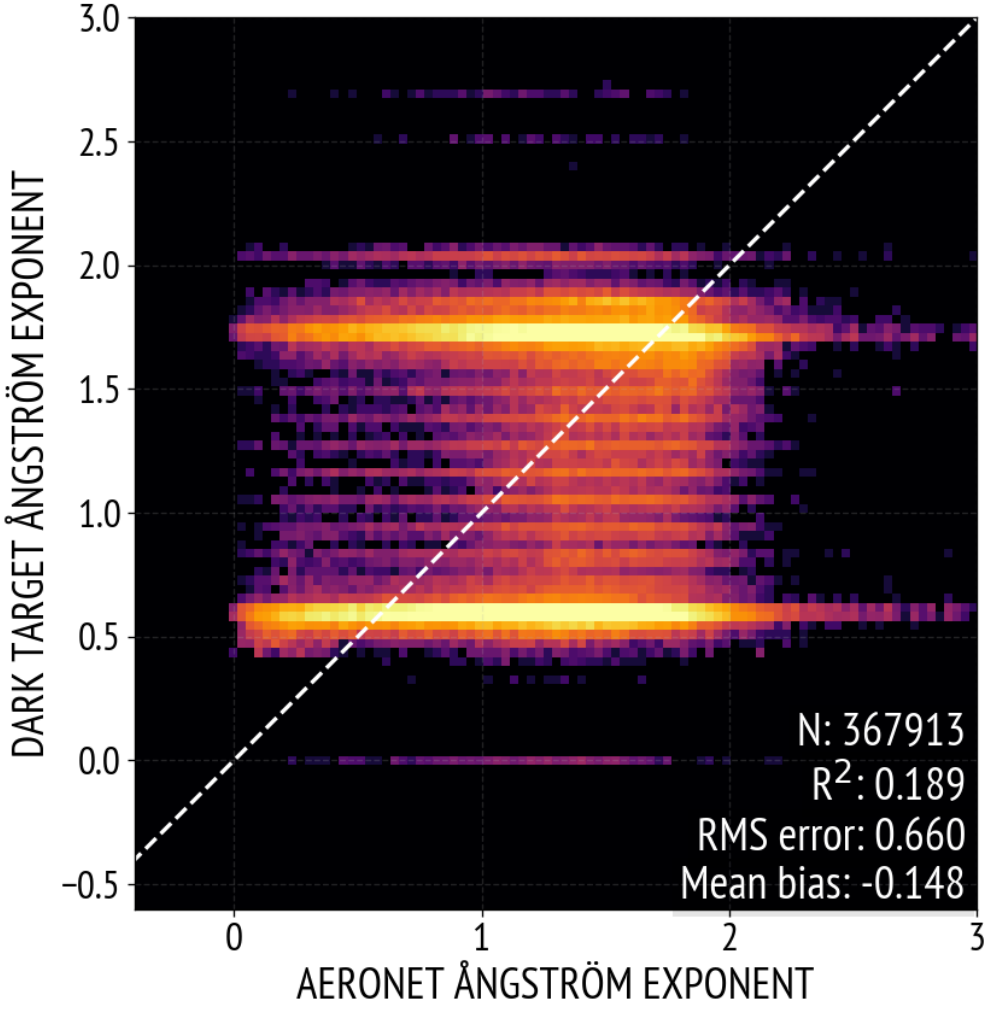
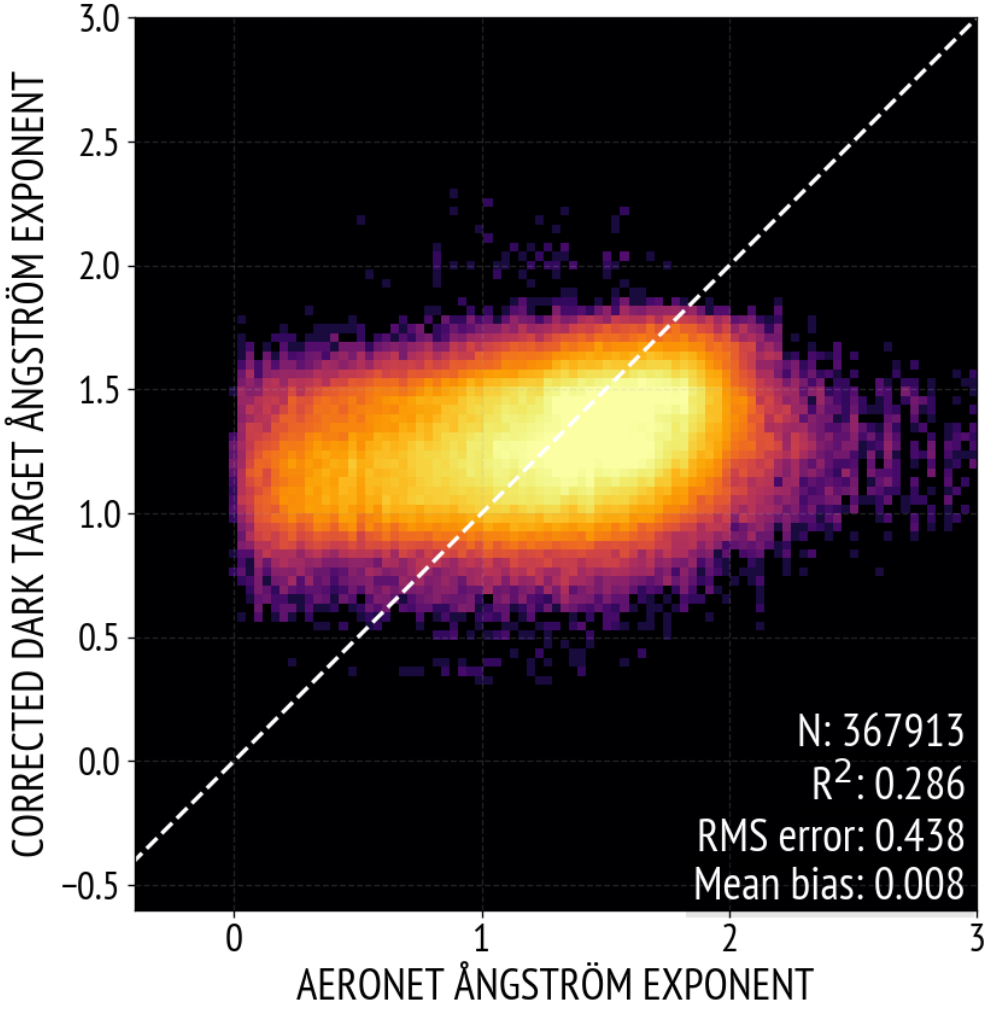
Correction with x = B01 & B07 TOA reflectances and
Dark Target B01 & B07 surface reflectances





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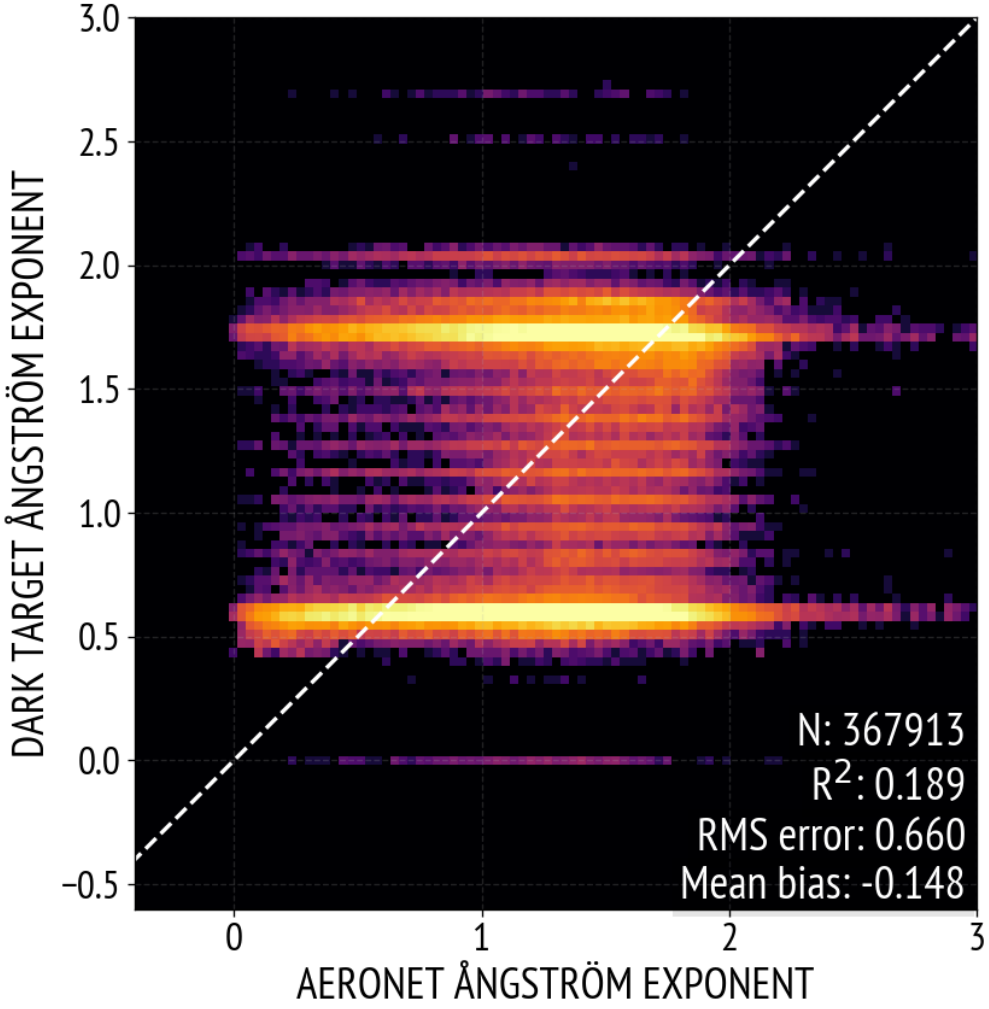
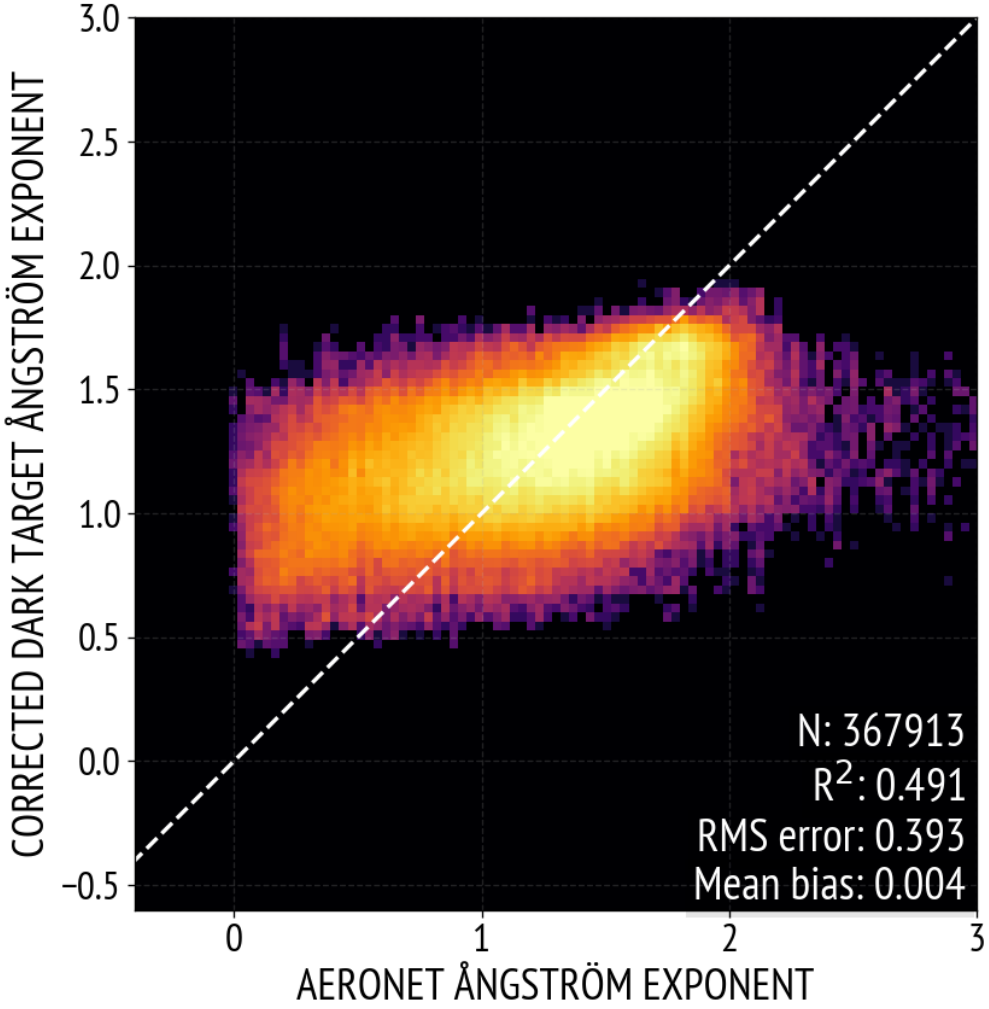
Correction with x = All available TOA reflectances, geometry, etc.





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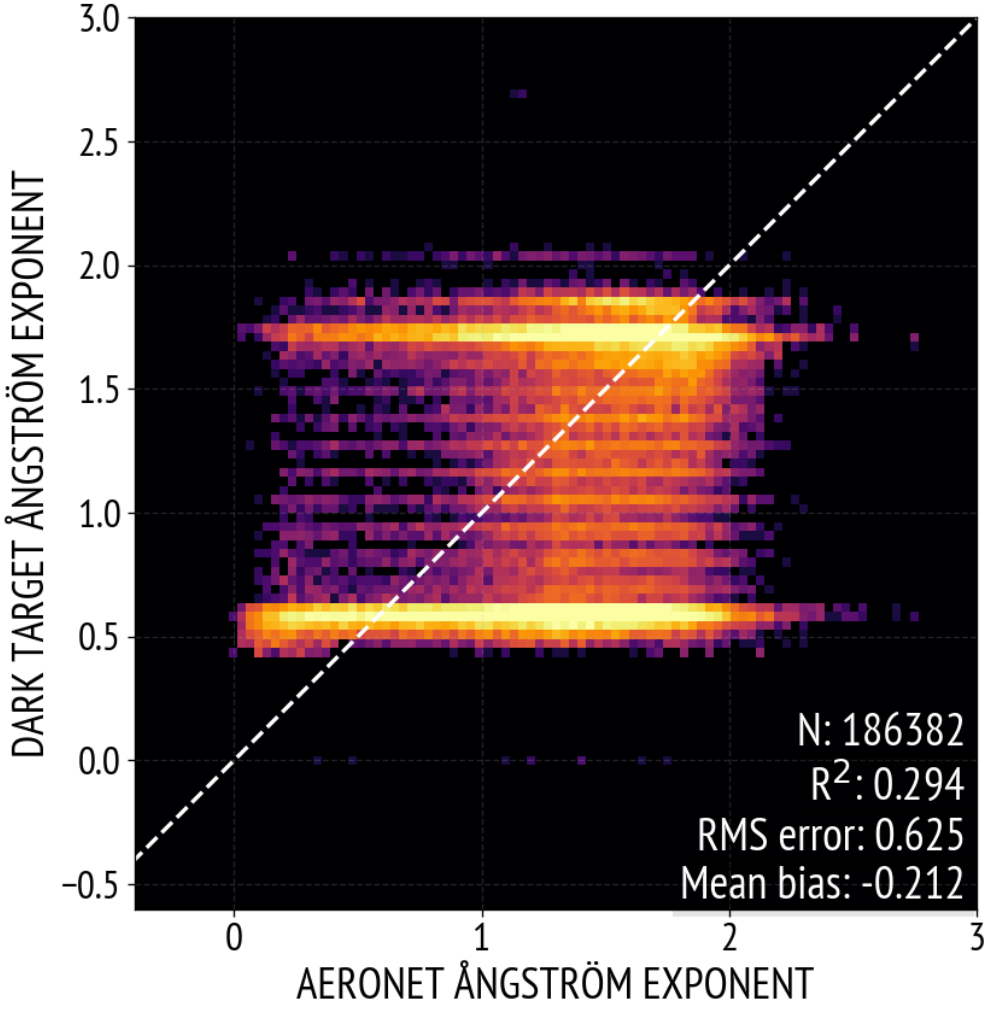
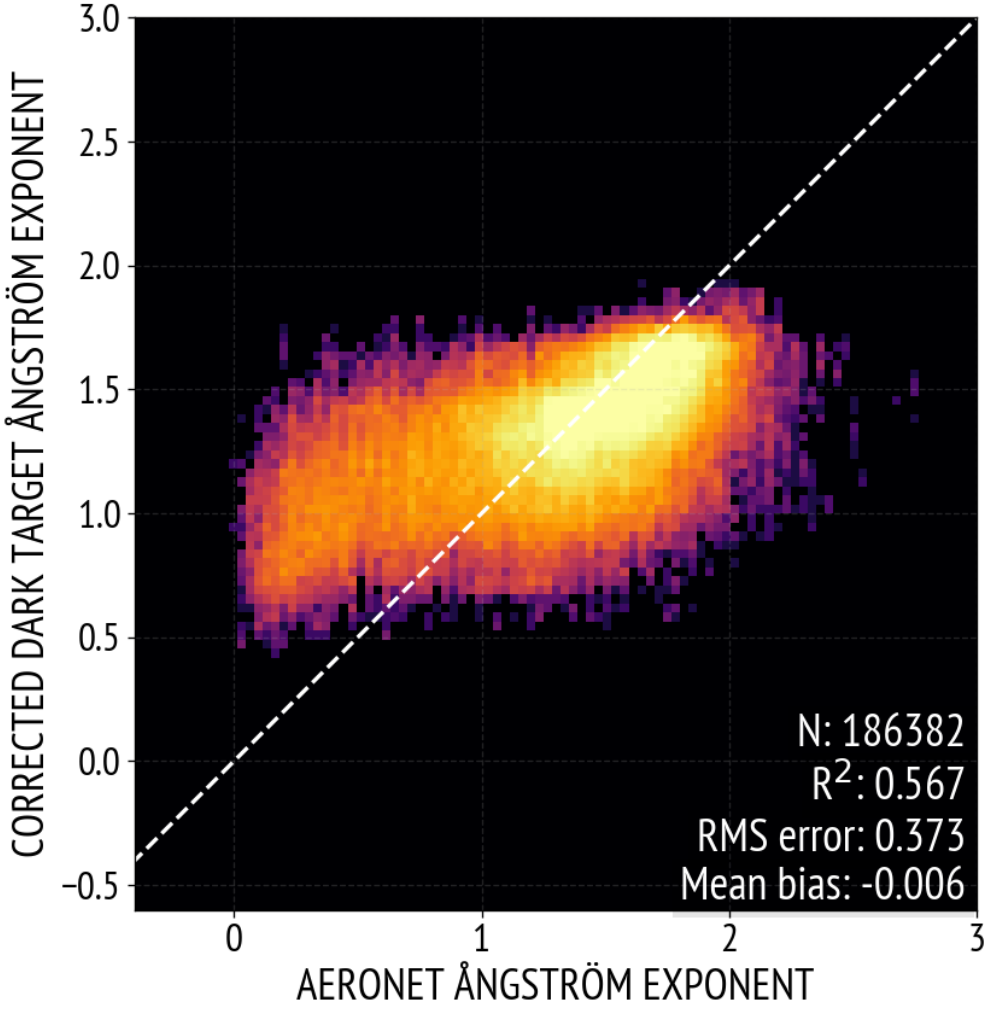
Correction with x = All available TOA reflectances, geometry, etc.
AERONET AOD > 0.1





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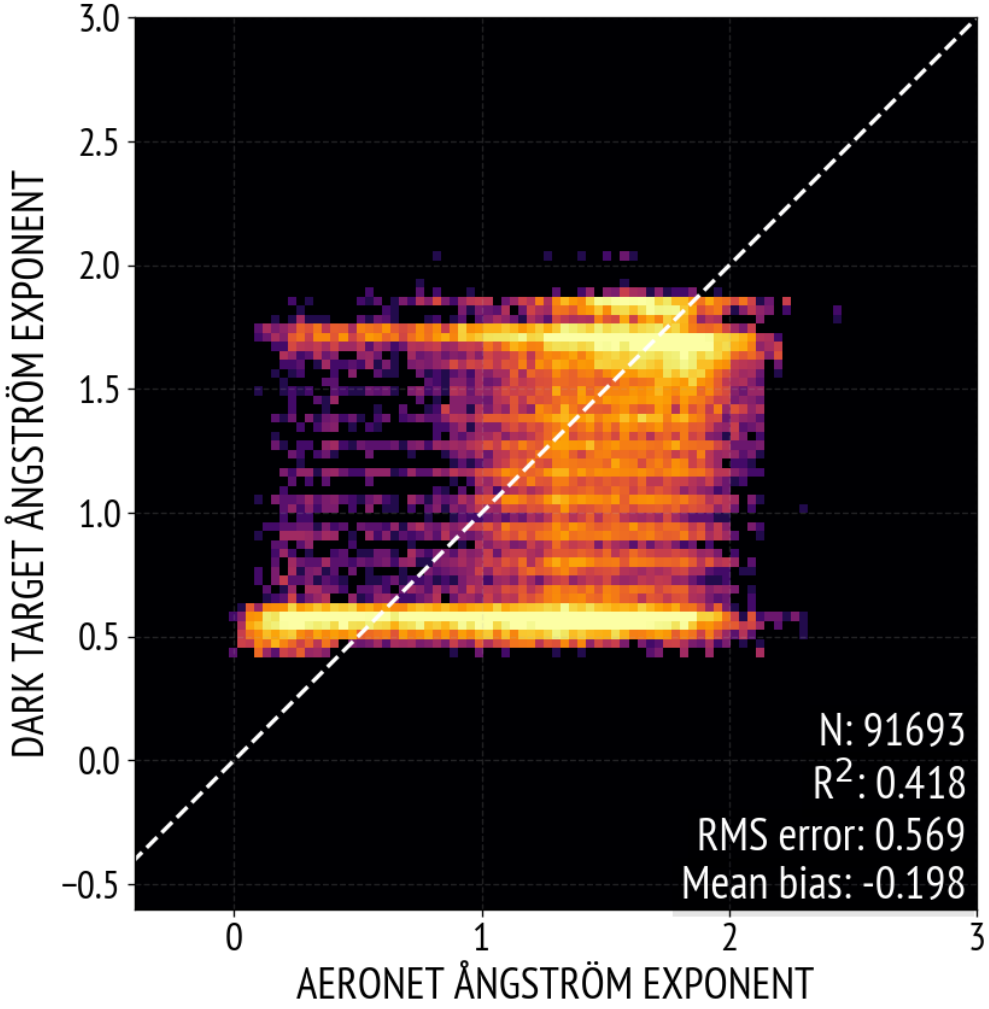
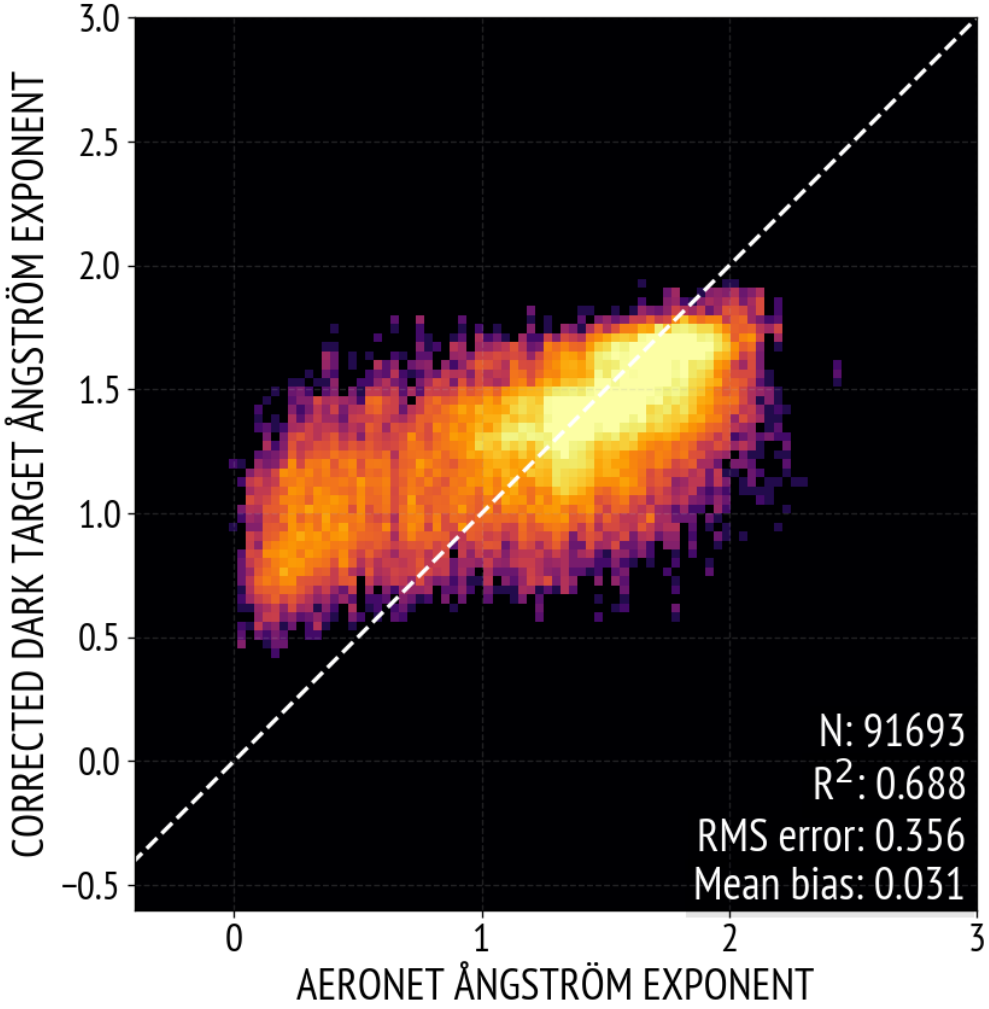
Correction with x = All available TOA reflectances, geometry, etc.
AERONET AOD > 0.2





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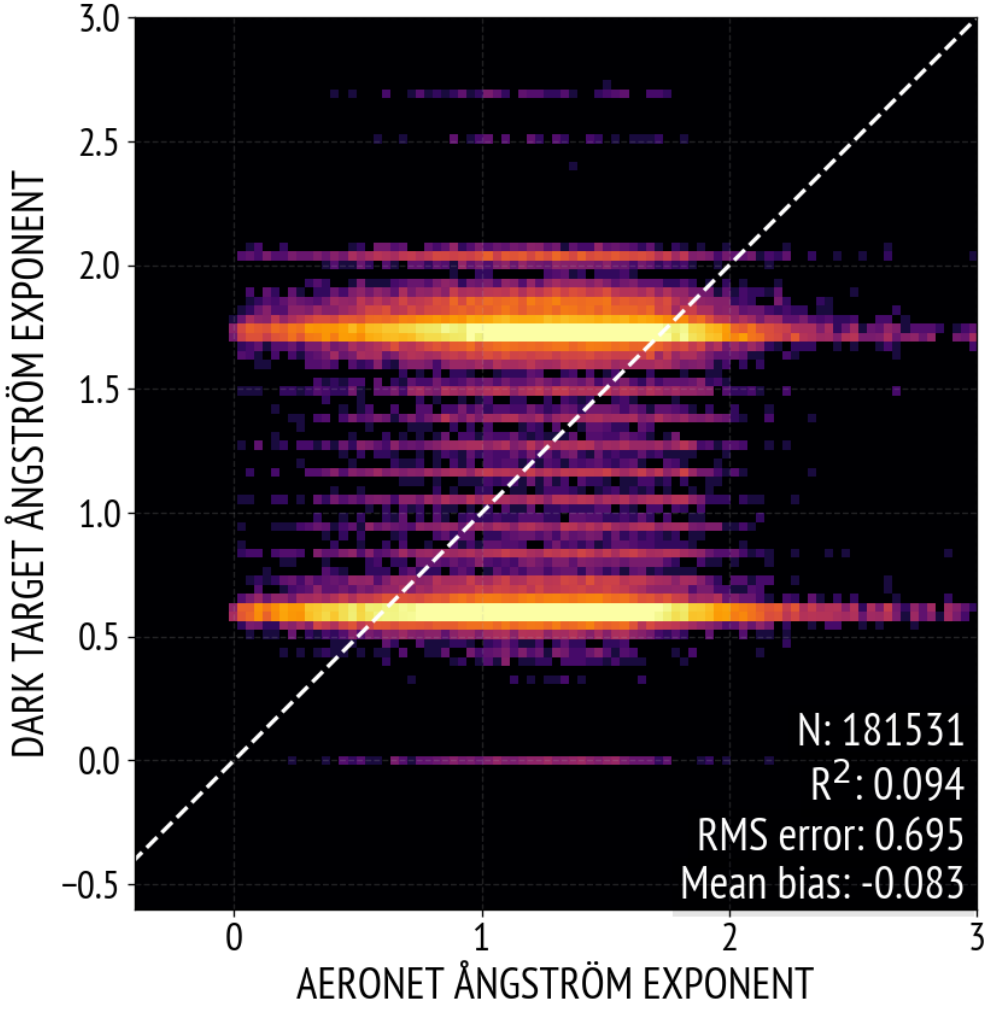
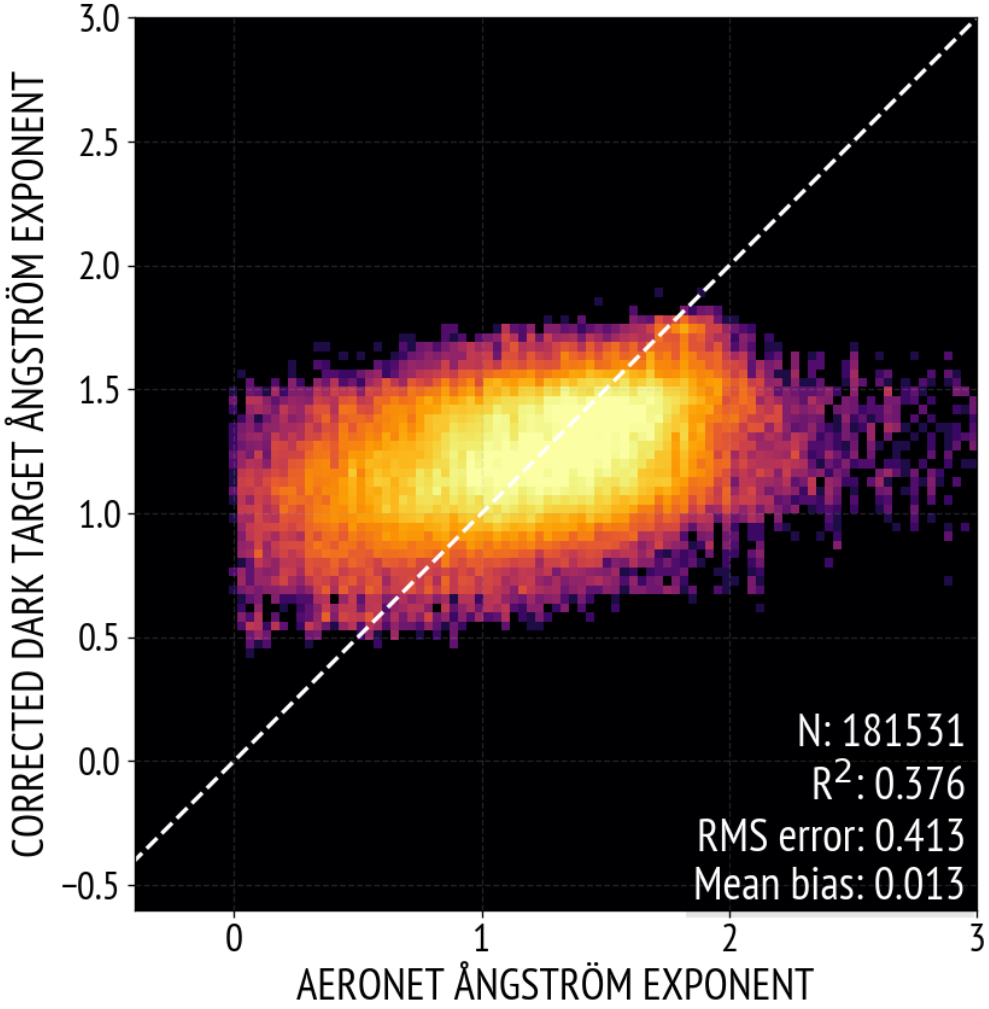
Correction with x = All available TOA reflectances, geometry, etc.
AERONET AOD < 0.1





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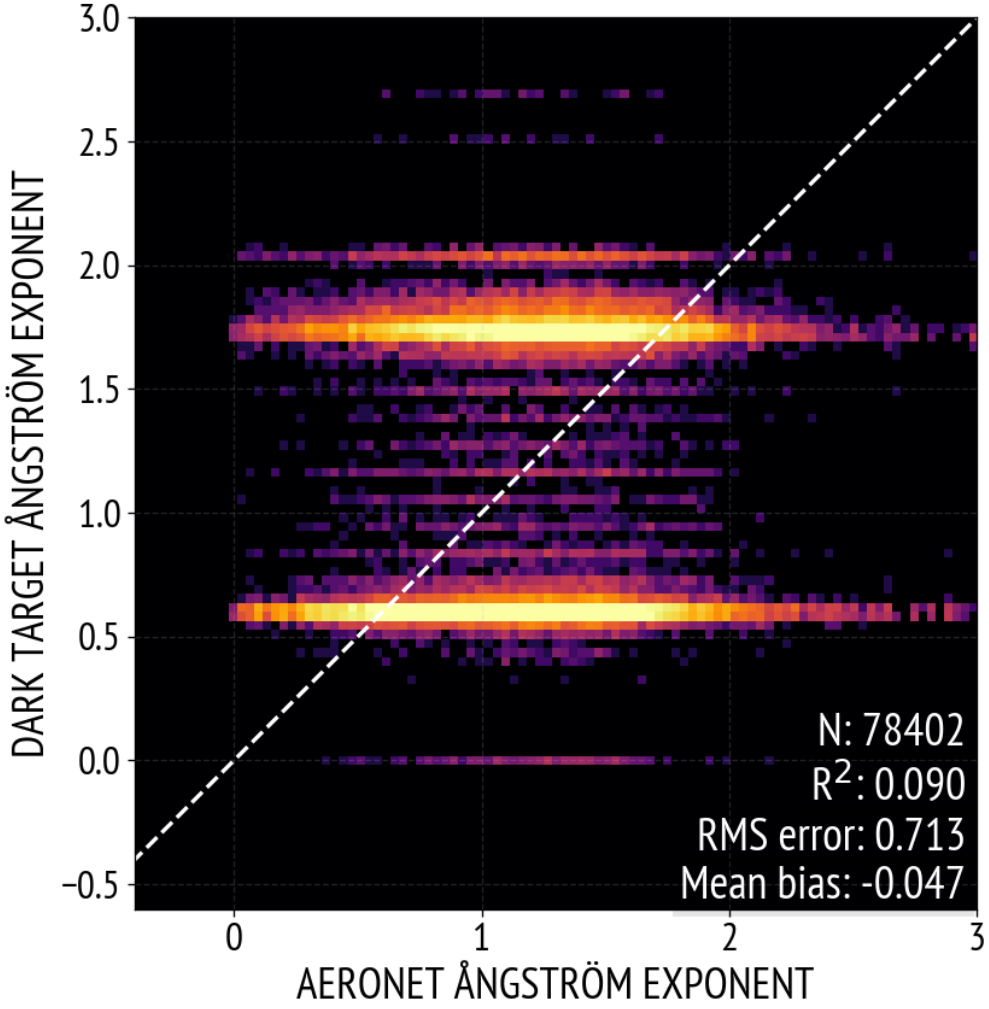
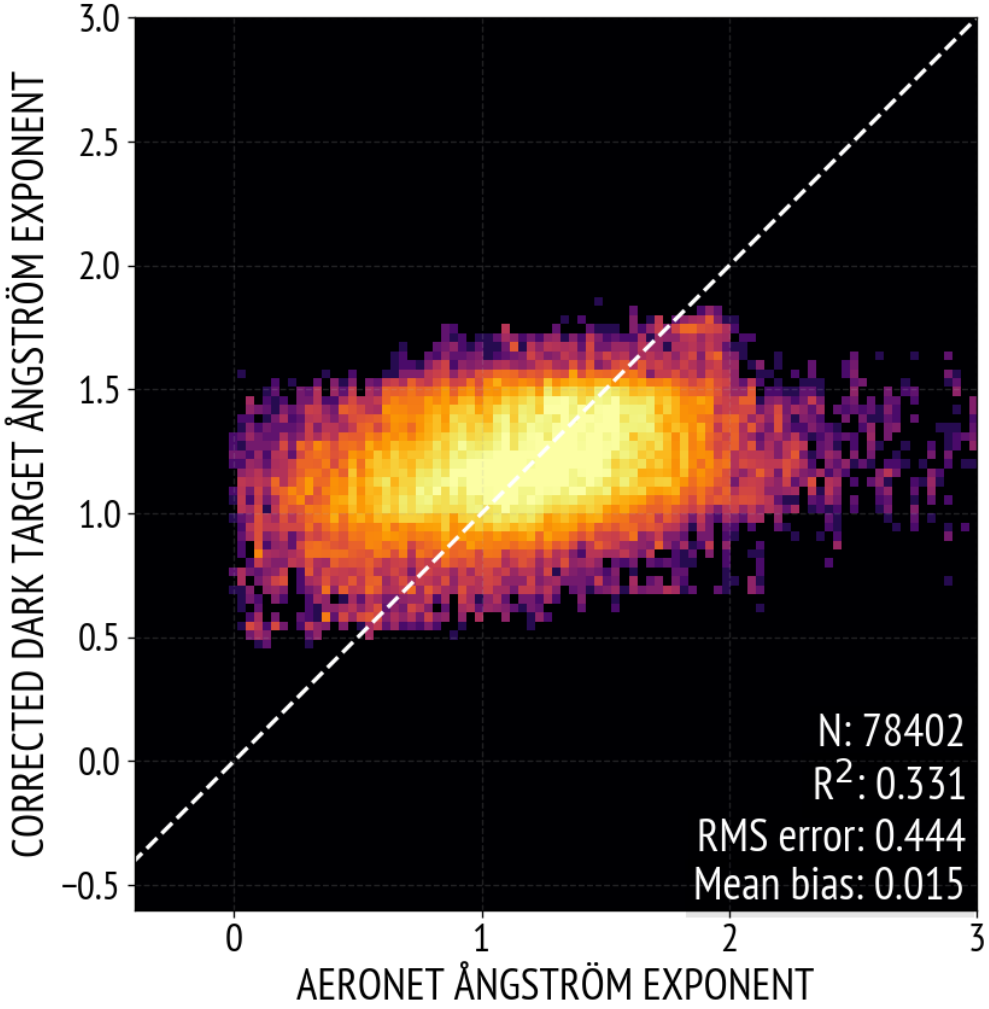
Correction with x = All available TOA reflectances, geometry, etc.
AERONET AOD < 0.05





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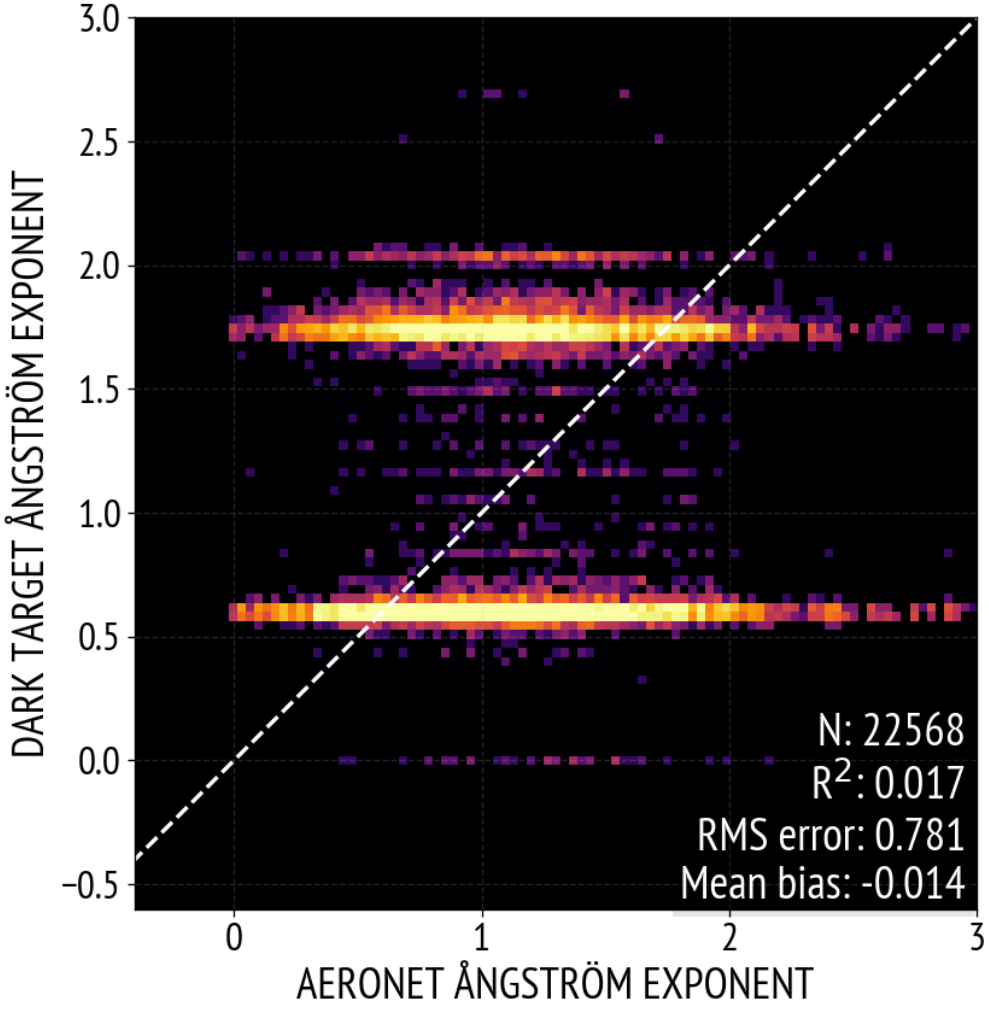
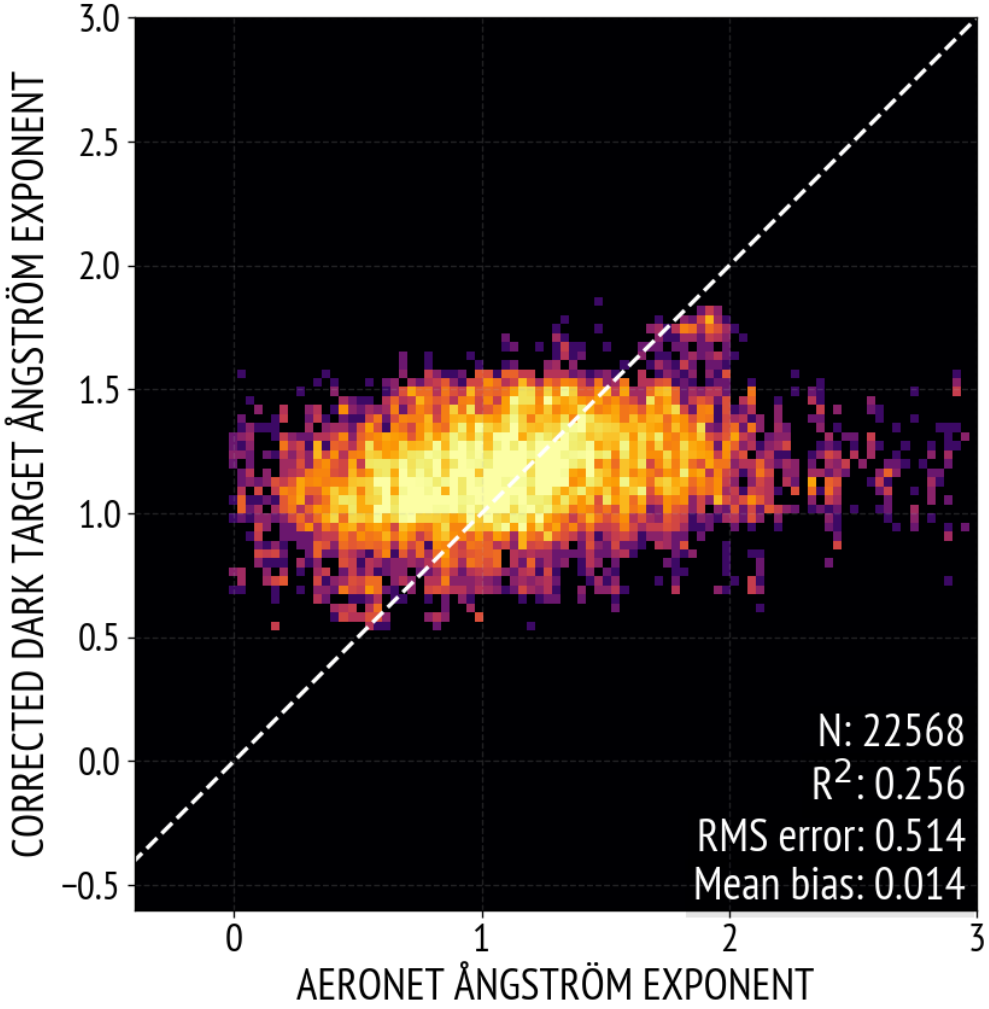
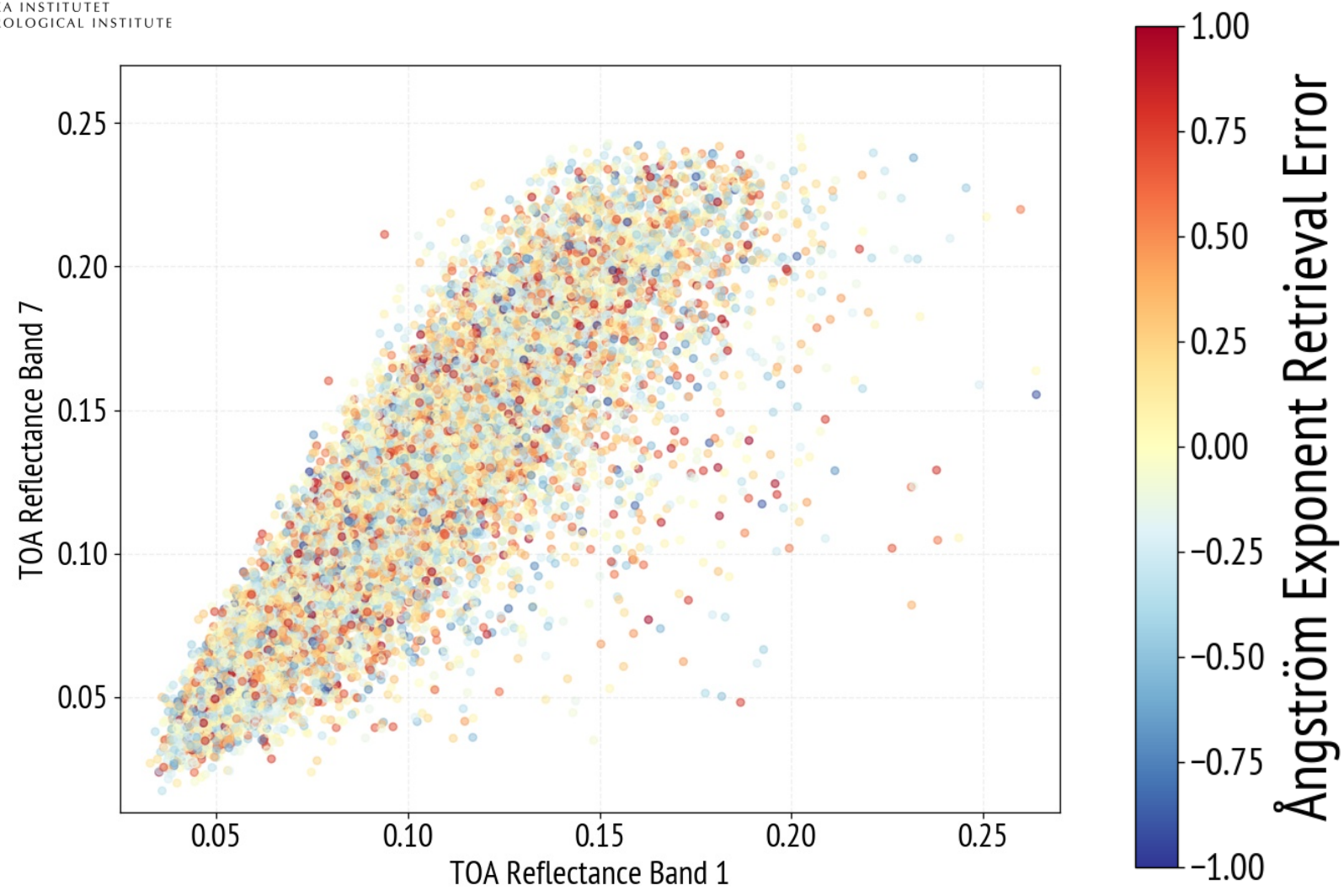
Correction with x = All available TOA reflectances, geometry, etc.
AERONET AOD < 0.025






TOA Reflectance Band 7
0.25
0.20
0.15
0.10
0.05
0.05
0.10
0.15
0.20
0.25
TOA Reflectance Band 1
Ångström Exponent Retrieval Error
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00

Current retrieval algorithms do not use all information in satellite observations for aerosol AE retrievals → algorithms can be improved!

[In this exercise all pixels were considered independent. If spatial correlations were modeled correctly, the results could be improved even further]

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Bayesian aerosol retrieval algorithm for MODIS AOD retrieval over land

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Try it yourself: https://github.com/TUT-ISI/BARalgorithm

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