Validierung der Atmosphärenkorrektur von Rapid-Eye Daten mit ATCOR

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Motivation

- Atmospheric correction of satellite data is necessary for many applications of remote sensing
- ATCOR is widely used for atmospheric correction of Rapid Eye data
- No uncertainty estimation of using ATCOR for atmospheric correction of Rapid Eye data

Method

- Atmospheric correction includes correction of molecular absorption, molecular scattering and aerosol effects
- Largest uncertainties arise out of aerosol correction due to spatial and temporal variation of aerosol amount and type

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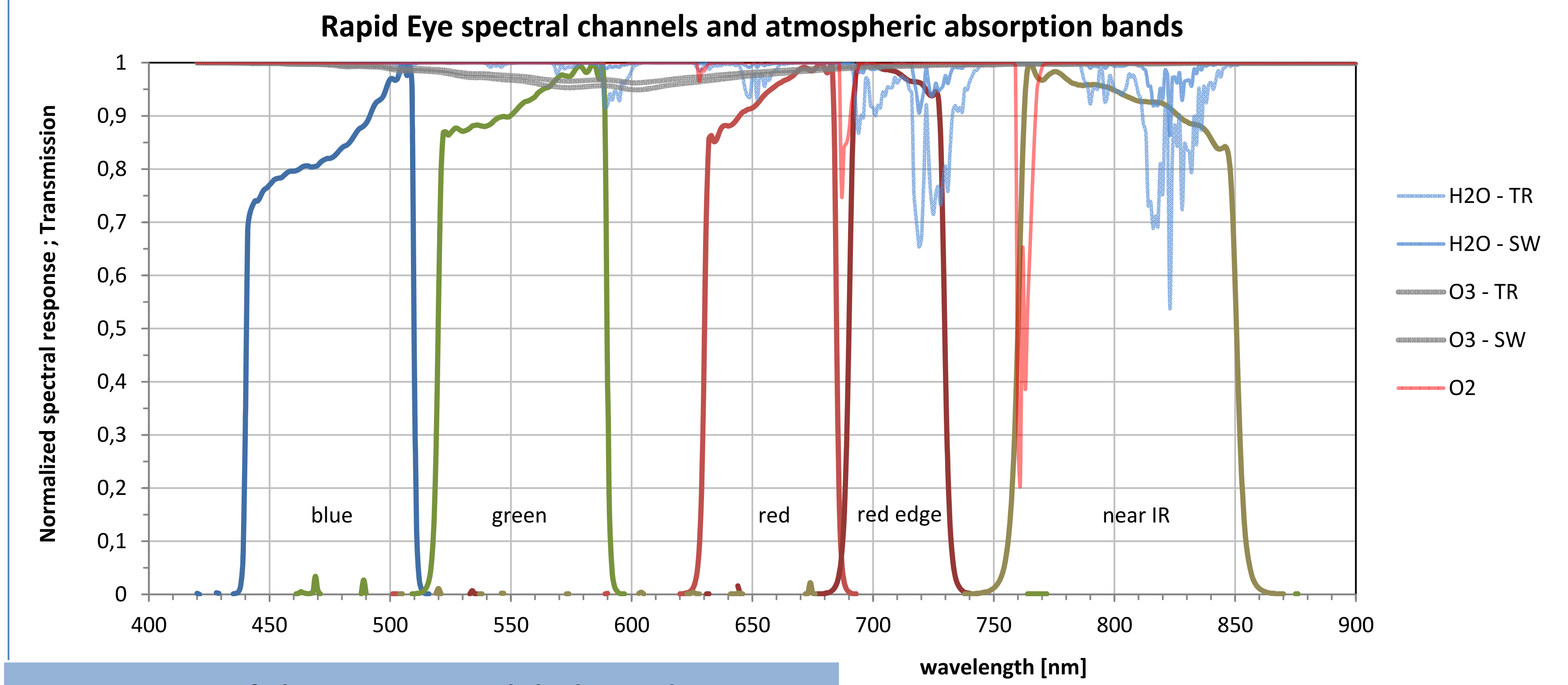
Atmospheric absorption within Rapid-Eye spectral channels



Variation of absorption optical thickness due to						
		Blue	Green	Red	RedEdge	NIR
H_2O	maximum variation	0.001	0.002	0.004	**0.045**	**0.024**
H_2O	typical variation	0.000	0.001	0.002	**0.024**	**0.013**
O_3	typical variation	0.001	0.004	0.002	0.001	0.000

-> Variations of absorption optical thickness due to variations of absorber amounts are small

Variation of atmospheric absorption and scattering within Rapid-Eye spectral channels

Variation of optical thickness due to absorption and scattering						
		Blue	Green	Red	RedEdge	NIR
H_2O	maximum variation	0.001	0.002	0.004	**0.045**	**0.024**
H_2O	typical variation	0.000	0.001	0.002	**0.024**	**0.013**
O_3	typical variation	0.001	0.004	0.002	0.001	0.000
τ^M	$\Delta p = \pm 15$ hPa	0.003	0.001	0.001	0.001	0.000
τ^A	maximum variation[2011]	0.38	0.35	0.34	0.30	0.28
τ^A	typical variation[2011]	0.11	0.10	0.09	0.07	0.06

Variation of optical thickness due to aerosols (2011)						
		440 nm	500 nm	550 nm	675 nm	870 nm
	Maximum value	0.46	0.42	0.40	0.34	0.31
	Mean value	0.22	0.19	0.16	0.13	0.09
	Median	0.20	0.17	0.15	0.12	0.08
	sdev	± 0.11	± 0.10	± 0.09	± 0.07	± 0.06
	Minimum value	0.08	0.07	0.06	0.04	0.03

- Variations of absorption optical thickness due to variations of absorber amounts are negligible relative to variations of AOT.
- Largest absorption influence is the H2O-absorption in the RedEdge band.
- Uncertainty of molecular scattering due to unknown surface pressure is negligible too.
- Both molecular scattering and absorption are smaller than the maximum variation of AOT in 2011 by about an order of magnitude.

- **Largest uncertainties arise out of aerosols**

Method

- Atmospheric correction includes correction of molecular absorption, molecular scattering and aerosol effects
- Largest uncertainties arise out of aerosol correction due to spatial and temporal variation of aerosol amount and type

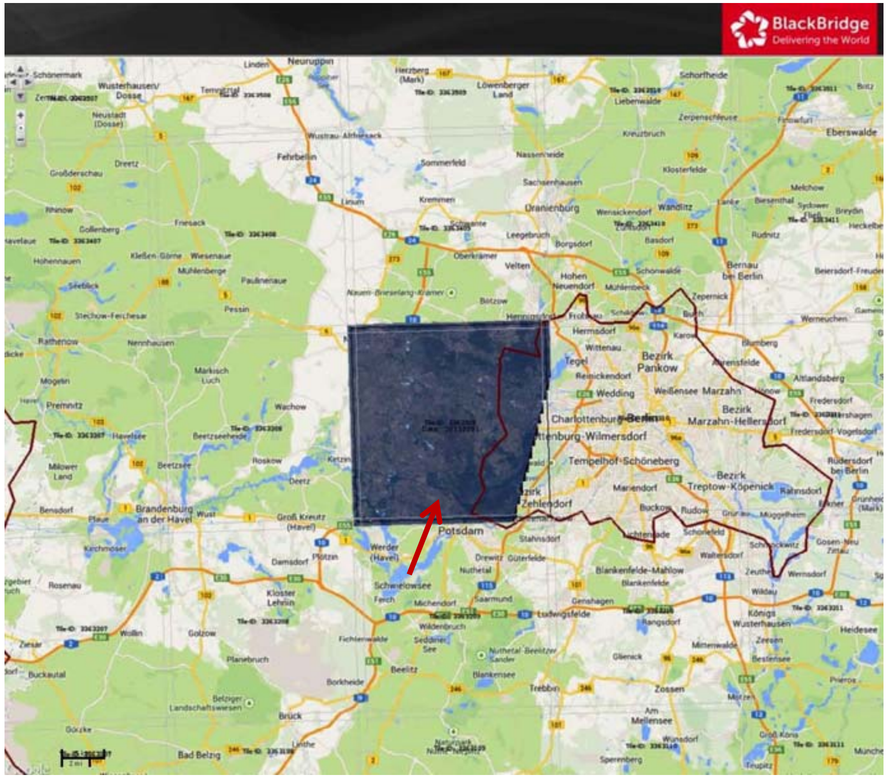
- Validation of atmospheric correction by validation of aerosol estimation
- ground-based measurements of vertical column AOT-spectra synchroneously to Rapid-Eye overpasses
- Comparison of aerosol retrieval from ATCOR with ground-based results

Rapid-Eye data

Target area: Potsdam-Bornstedt

Tile 336 3309

Date	clouds	Black fill	ground-based
01.03.2011	0 %	7 %	90 min after RE
20.04.2011	0 %	11 %	2,5 h after RE
06.09.2011	13 %		1 h before RE
13.10.2011	22 %		6 min after RE
08.11.2011	**0 %**	21 %	**at overpass time**



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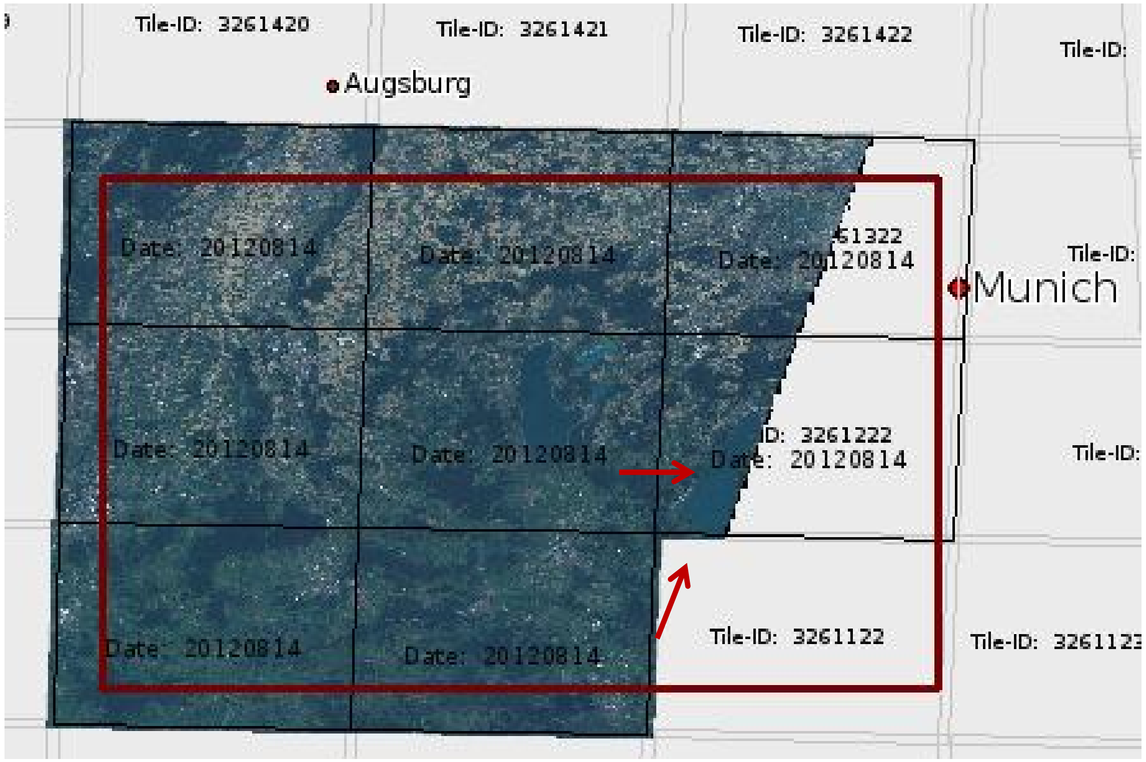
Rapid-Eye data

Target area: Lake Starnberg

Tiles 326 1122, 326 1222

Date	clouds	Black fill	ground-based
14.05.2012	4 %	47 %	**at overpass time**
14.08.2012	**0 %**	64 %	75 min before RE



Algorithm for Rapid-Eye data

- Atmospheric correction **ATCOR2** for flat terrain,
  Red/NIR band algorithm [Richter, R,, Schläpfer, D,, & Müller, A, (2006)]
- variable Visibility over the scene
- Aerosol type set to rural

AOT550	VIS
0.05	204 km
0.10	91 km
0.15	56 km
0.20	40 km
0.25	31 km
0.30	25 km
0.35	21 km
0.40	18 km
0.45	16 km
0.50	14 km

- Conversion between Visibility (VIS) and vertical column aerosol optical thickness (AOT)

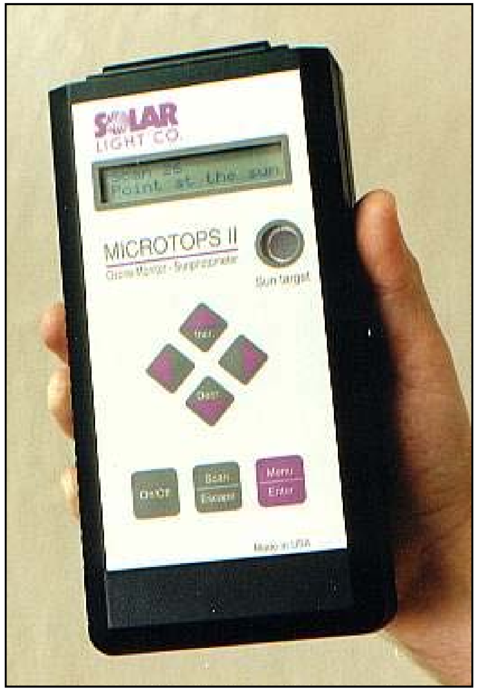
$$AOT550 = e^{a(z)+b(z)\times\ln(VIS)}$$

z=0 km : a = 1.54641 b = -0.854022

Ground based data

- 2 Microtops II Instruments, Ozonometer and sunphotometer

Optical channels **Ozonometer**	Optical channels **Sunphotmeter**
305.5 ±0,3 nm FWHM 2,0 nm	380 ± 0,4 nm FWHM 4 nm
312.5 ±0,3 nm FWHM 2,0 nm	440 ± 1,5 nm FWHM 10 nm
320.0 ±0,3 nm FWHM 2,0 nm	500 ± 1,5 nm FWHM 10 nm
936 ±1,5 nm FWHM 10 nm	675 ± 1,5 nm FWHM 10 nm
1020 ±1,5 nm FWHM 10 nm	870 ± 1,5 nm FWHM 10 nm



- View angle: 2.5°
- Radiation captured by collimators and bandpass filters radiate onto the photodiodes
- signals from the photodiodes are processed in series
- in first three channels GaP photodetectors (Gallium Phosphate)
- Silicon photodetectors are used for the visible and NIR channels

Algorithm for ground-based data

- Coupled analysis of sunphotometer and ozonometer measurements

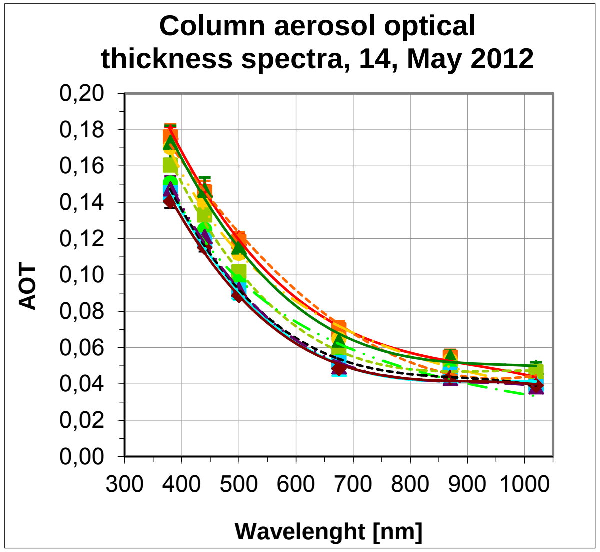
[Pflug, B,, (2012)]

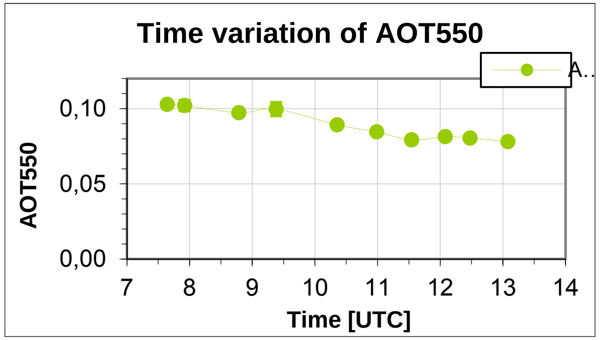
- Results:

  Vertical column
  - AOT-spectra -> AOT550 -> VIS
  - Ångstrœm-exponent α $\{ \tau_\lambda = \tau_{1\,\mu m} \cdot \lambda^{-\alpha} \}$

Aerosol type	Ångstrœm-exponent α at RH 99%	Ångstrœm-exponent α at RH 0%
Maritime model	0.07	0.56
Rural model	1.13	1.54
Urban model	1.00	1.44
Desert model	-0.1 (wind 30 m/s)	1.6 (wind 0 m/s)

  - Effective particle radius [µm]
  - ozone content [DU]
  - water vapour content [cm precipitable water column]

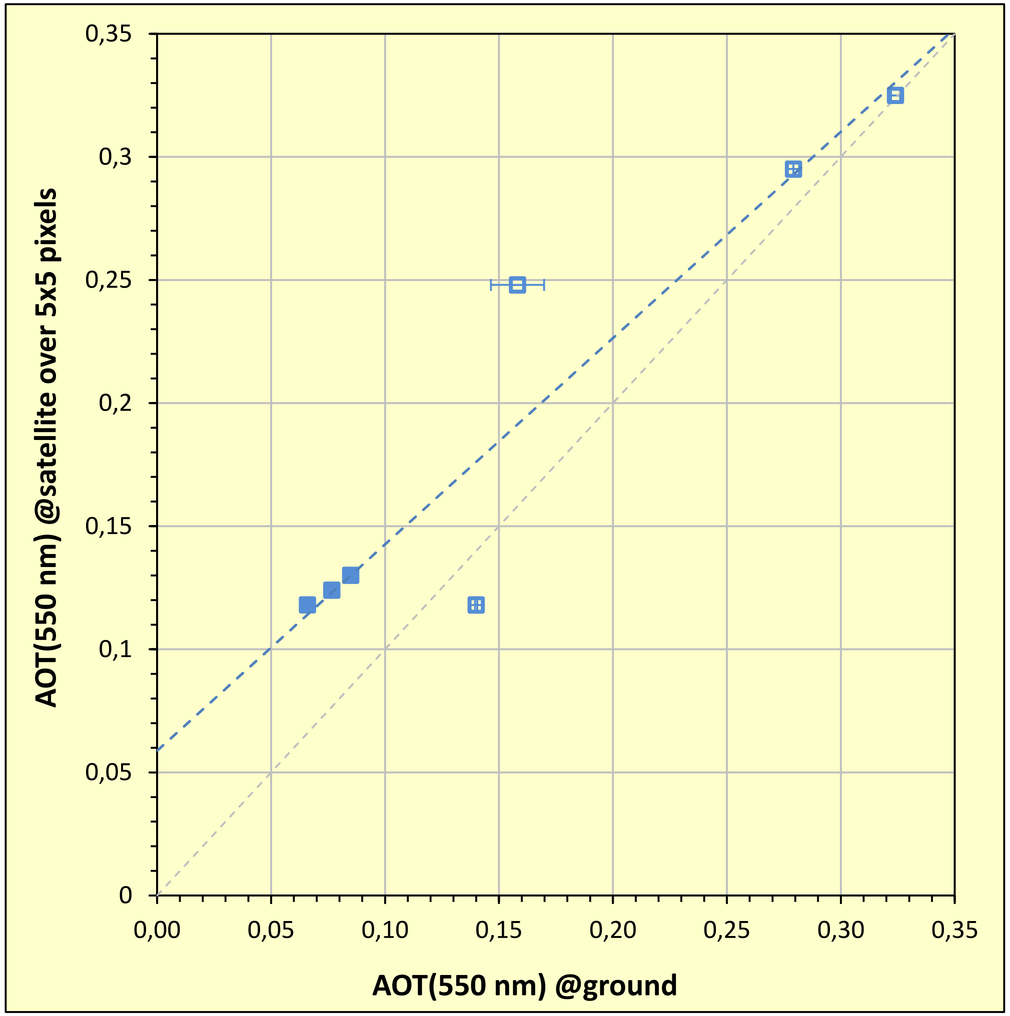




Ground-truth datasets for Rapid-Eye overpasses

Date	Rapid-Eye overpass time [UTC]	Ground-truth measurement time [UTC]	AOT550	VIS	Ångstrœm-Exponent
01.03.2011	10:09	11:40 – 11:45	0.14 ± 0.00	58 km ± 0.5 km	1.4 ± 0,0
20.04.2011	10:15	12:55 – 13:00	0.28 ± 0.00	27 km ± 0 km	1.7 ± 0,0
06.09.2011	10:13	09:10 – 09:15	0.08 ± 0.00	123 km ± 4 km	1.0 ± 0,0
13.10.2011	10:09	10:15 – 10:20	0.06 ± 0.00	155 km ± 5 km	0.98 ± 0,0
08.11.2011	10:15	08:15 – 14:30	0.32 ± 0.00	23 km ± 0.5 km	1.2 ± 0,0
14.05.2012	10:23	06:30 – 13:10	0.08 ± 0.00	100 km ± 2 km	1.6 ± 0,0
14.08.2012	10:11	06:20 – 09:00	0.16 ± 0.01	49 km ± 4 km	1.8 ± 0,1

Comparison ATCOR <-> ground-truth within 5x5 pixel surrounding area



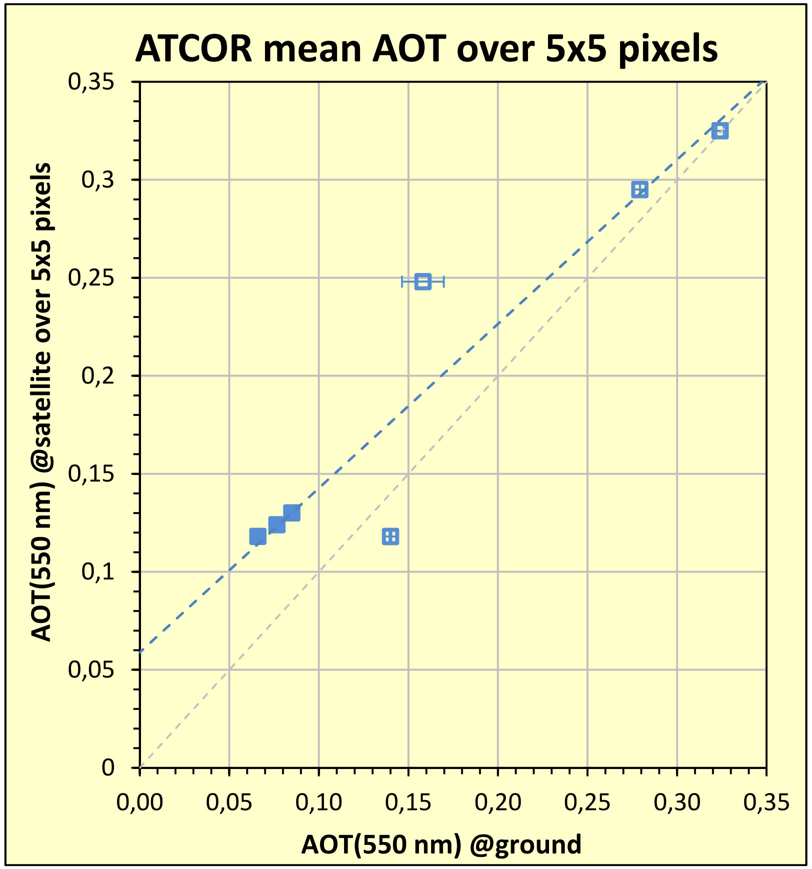
Mean difference between ATCOR and ground-truth:

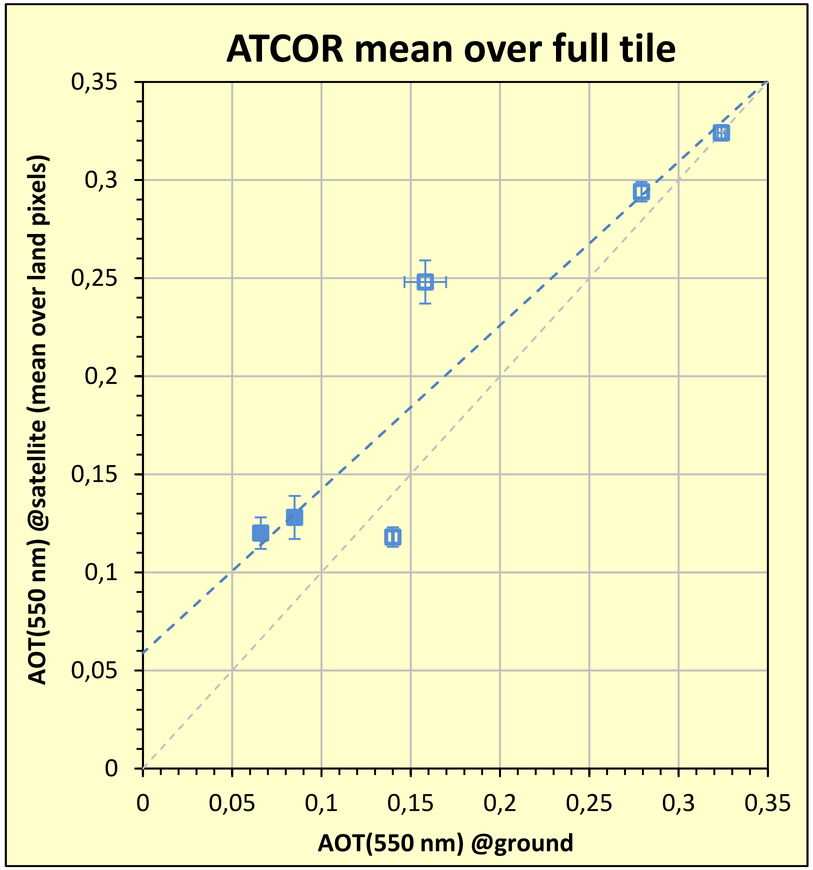
- **0.03** for cloudless scenes
  (0.01 without outlier)
- **0.04** for all scenes
  (0.03 without outlier)

Maximum difference:

- **0.05** without outlier
  (for outlier 0.09)

Comparison ATCOR <-> ground-truth within full Rapid-Eye tile





- Rapid-Eye tiles can be processed with a mean AOT for each tile.

Discussion of uncertainty

Requirements on the processing of HSI (EmMAP) data: [EN-DLR-RS-006, p. 55-56]

- o for land applications Δ $AOT_{550} < 0.06$ for $\rho_{2,1} < 0.1$ (dark pixels)
  Δ $AOT_{550} < 0.10$ for $0.1 < \rho_{2,1} < 0.16$
- o for water applications Δ $AOT_{550} < 8\%$

Δ $AOT_{550} \approx 0.04$ corresponds approximately to $\Delta\rho \approx 0.004$ [Kaufman et,al, 1997]

Requirements on the processing of HSI (EmMAP) data:

- o for land applications $\Delta\rho < 0.01$
- o for water applications $\Delta\rho < 10\%$ outside sun-glint contaminated scenes

Requirements on the processing of HSI (EnMAP) data mostly achieved

for the investigation area and the small number of synchroneous overpasses.

Aerosol type selection for processing Rapid-Eye scenes

- Only 4 aerosol models available in ATCOR

- Maritime and rural aerosol models give nearly identical results
- Urban aerosol gives significantly different AOT due to aerosol absorption
  (mean AOT-difference ATCOR to ground-truth is 0.17)

- Recommendation: Set the aerosol type to a model reasonable for your study area.

Summary and outlook

- Atmospheric correction algorithm ATCOR was validated on the level of aerosol retrieval uncertainties.
- Mean uncertainties are $\Delta AOT550 \approx 0.04$ corresponding approximately to $\Delta\rho \approx 0.004$
- More satellite overpasses of Rapid-Eye synchroneous to atmospheric ground-truth measurements are necesssary.
- Test site Potsdam gives a very good opportunity to realize this.

- ATCOR has shown a very nice performance, but nevertheless there are improvements necessary.
- Developing AC2020 – a new atmospheric correction in heritage of ATCOR.

References:

1. Richter, R,, Schläpfer, D,, & Müller, A, (2006), An automatic atmospheric correction algorithm for visible / NIR imagery, International Journal of Remote Sensing, 27(10), 2077–2085, doi:10,1080/01431160500486690
2. Pflug, B,, (2012), Ground based measurements of aerosol properties using Microtops instruments, AIP Conf, Proc, 1531, 588 (2013); doi: 10,1063/1,4804838, View online: http://dx,doi,org/10,1063/1,4804838
3. V, Bargen, A,, Grosser, J,, (2010), Environmental Mapping & Analysis Program (EnMAP), Ground Segment Requirements Document, GRD, EN-DLR-RS-006
4. Kaufman, Y,J,, Wald, A,E,, Remer, L,A,, Gao, BC, Li, RR, Flynn, L,, (1997), The MODIS 2,1-µm Channel-Correlation with Visible Reflectance for Use in Remote Sensing of Aerosol, IEEE Transactions on Geoscience and Remote Sensing, Vol, 35, No, 5, p. 1286-1298