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Colocation day GAIA-CLIM – FIDUCEO

Aerocol closure for AVHRR (FIDUCEO)

Thomas Popp (DLR)

Objectives / background

AVHRR aerosol CDR

- Total Aerosol Optical Depth (AOD)
- Over land - Europe / Northern Africa
- 2002 – 2012
- Comprehensive uncertainty characterization

Background

- AOD retrieval is ill-posed inversion problem
- AVHRR is a weak instrument for aerosol (calibration, few channels)
- AVHRR offers potential long historic record to 1980s
- Uncertainty characterization is crucial for valuable CDR

- Build on ESA Aerosol_cci legacy and develop approaches further
- Build on DLR-internal TIMELINE project

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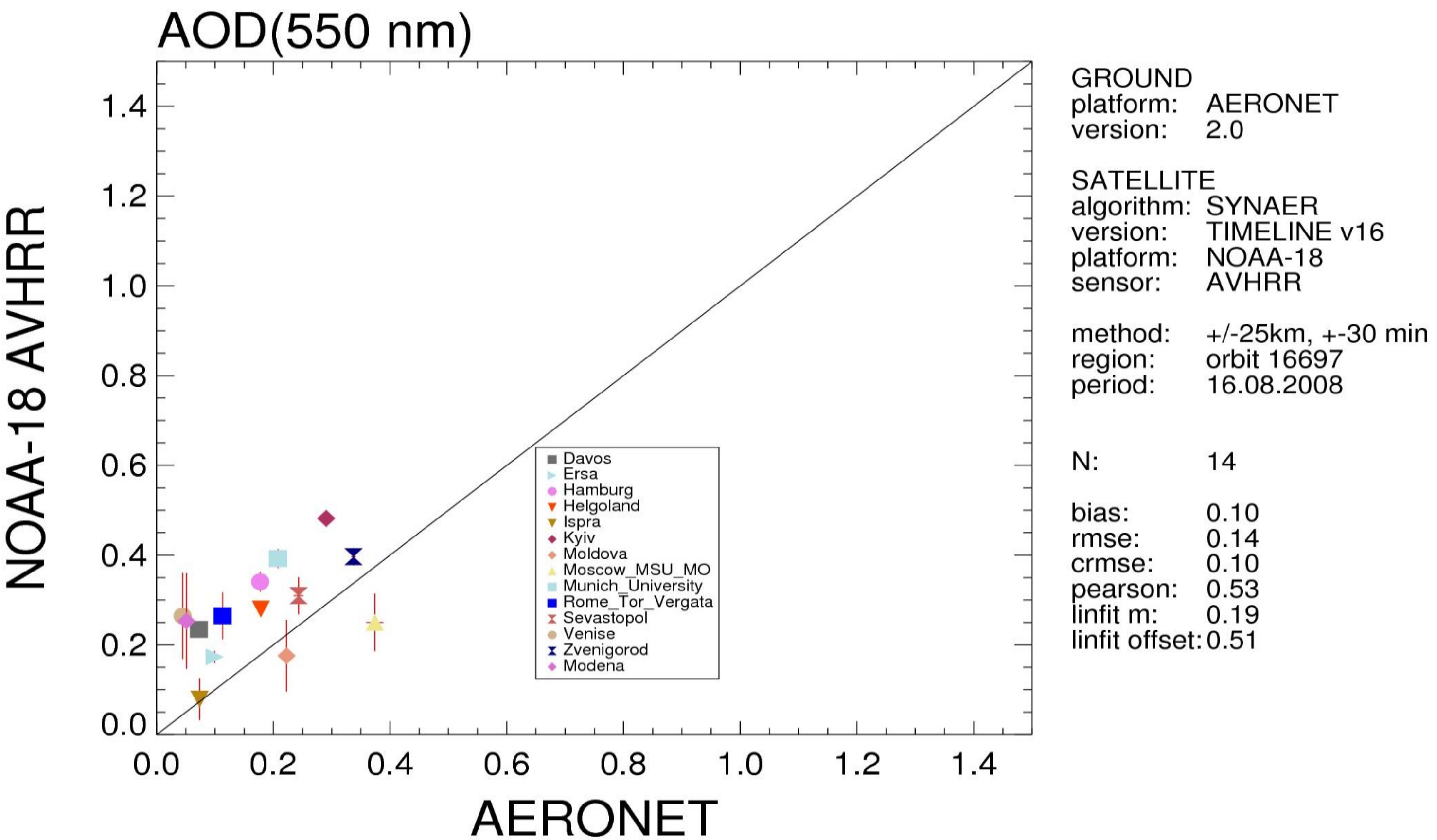
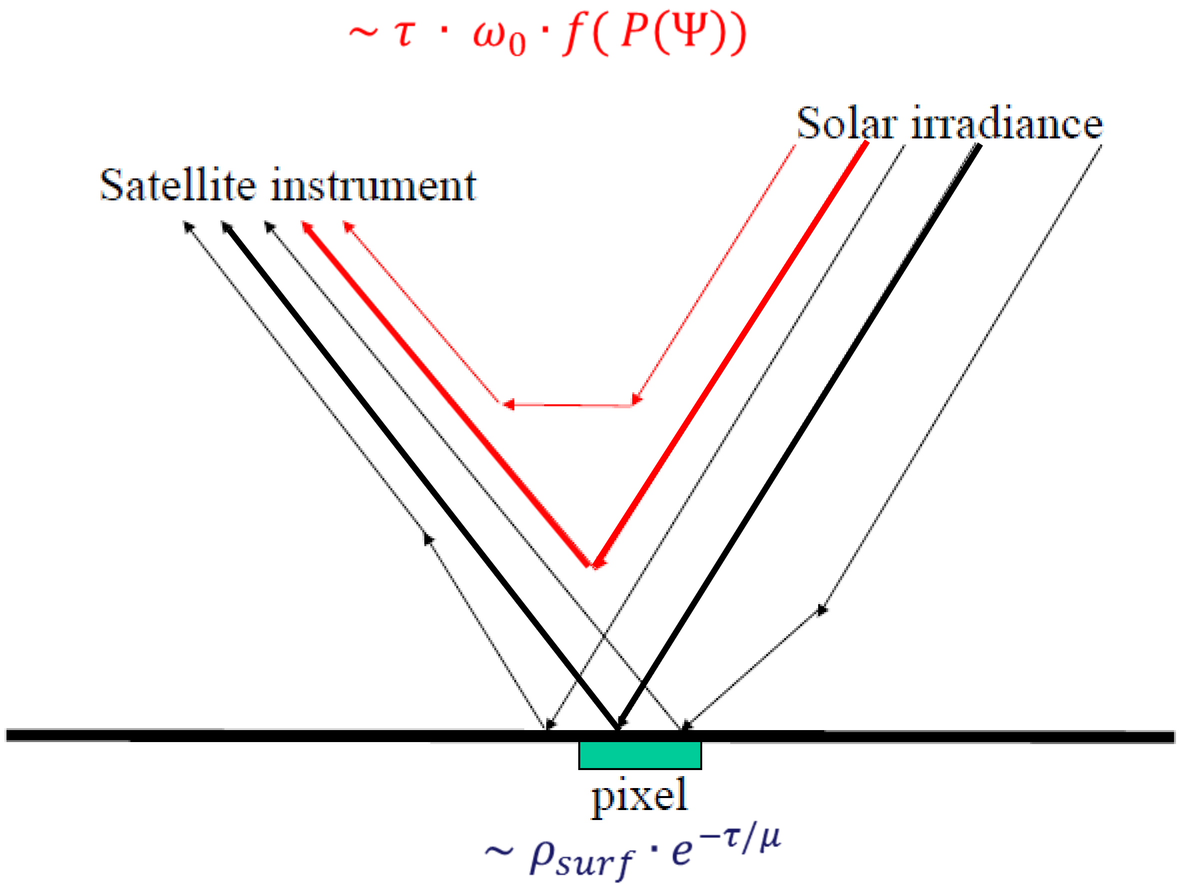
Initial example



16. 08. 2008 (NOAA-18)

Aerosol retrieval signal for aerosol optical depth AOD or τ



Traceability chain

Simple algorithm fitting single channel retrieval

- $R_{TOA} = \frac{\pi L}{\mu_0 E_0}, \mu_0 = \cos(\theta_0)$

Retrieval operator

- $AOD_{670} = f(R_{TOA}; \theta_S, \theta_0, \Delta\varphi;\ Alb_{surf}, aerosol_{type};\ \tau_i^{trace\ gases}; h_{surf})$

Principle of aerosol retrieval

Single channel LUT inversion at best-suited dark fields

Satellite signal „measures“ non-linear geometry-dependant combination of

- aerosol extinction / AOD
- phase function / single scattering albedo
- surface reflectance

Needed auxiliary information

aerosol type (climatology, ensemble)

surface brightness

Additional steps

selection of dark fields / interpolation between dark fields

cloud masking (combined threshold tests)

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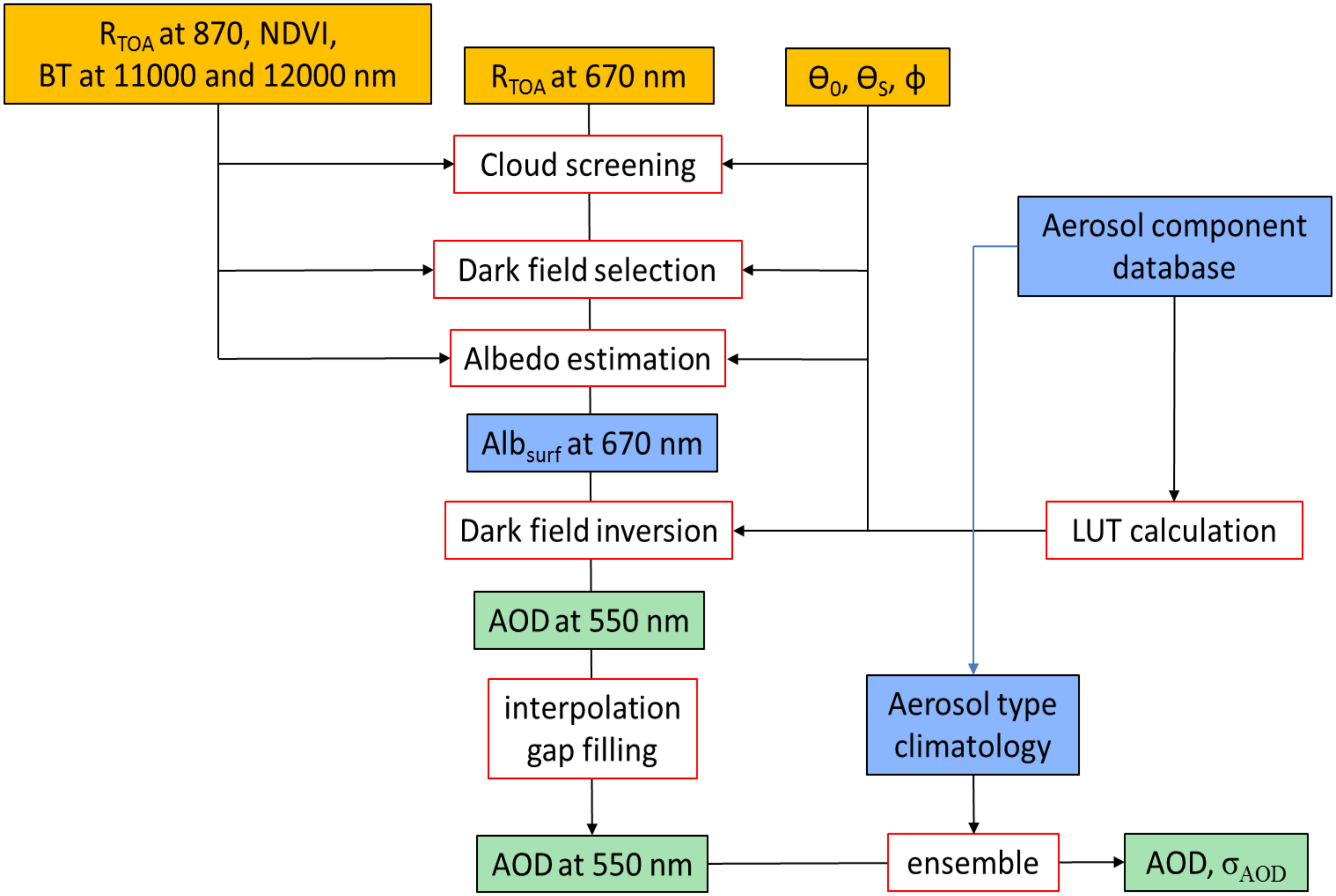
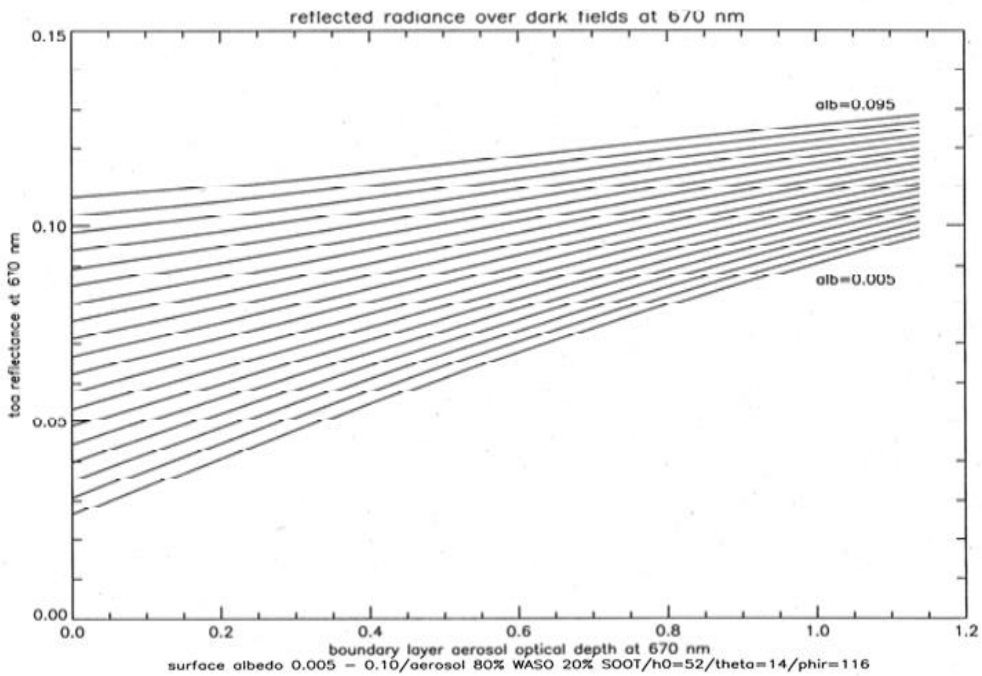
Block diagram



Traceability chain

Main functional dependancy

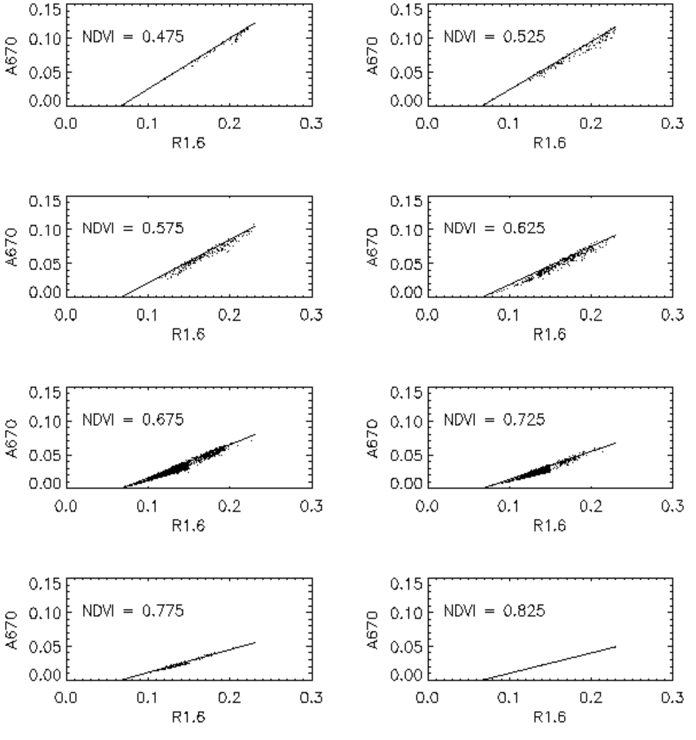
- $AOD_{670} = f(R_{TOA}; Alb_{surf})$
- Parameterized with step-wise 2nd order polynomials
- For dark fields

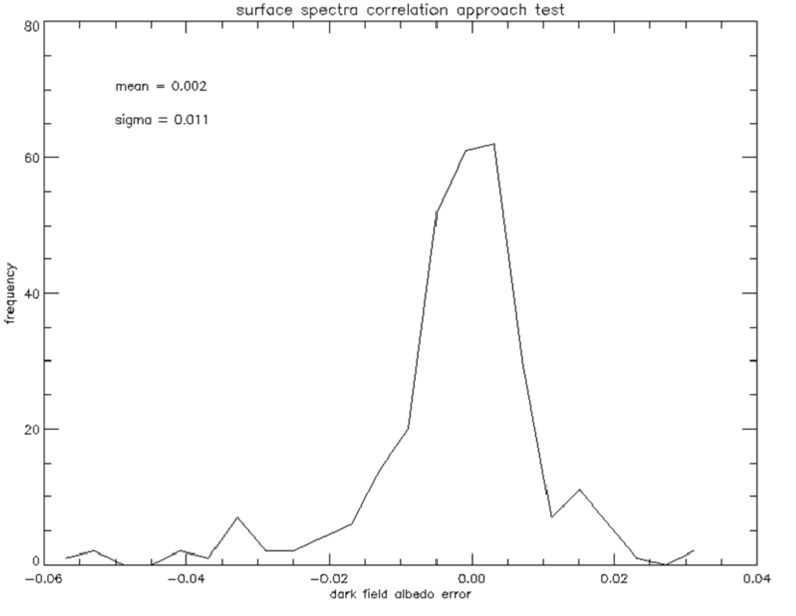


Dark field method

Parameterization

- $Alb_{surf}^{670} = a\, R_{TOA}^{1670} + b$
- with a = -1.5 NDVI +1.5 and b = 0.1 NDVI – 0.01





Sources of uncertainty

Source of uncertainty	Description	Qualitative estimate of contribution
Cloud screening and safety zone	Capabilities depend on available spectral range (e.g. thermal bands are important); safety zone also masks elevated AOD around clouds	High for UV/VIS sensors, medium for stratospheric algorithms
Overpass time	Polar orbiting sensors provide typically one or two sun-synchronous overpass times per day	High when comparing to different sensors or against models
Land surface reflectance (BRDF)	Can be estimated from vegetation index and/or mid-infrared bands, drawn from a climatology or ECV, or retrieved alongside AOD from multi-view data	High for nadir-only sensors, with larger uncertainty at higher reflectances
Ocean surface reflectance	Estimated using white caps parameterisation and possibly a climatology of ocean colour	Medium
Calibration	Absolute radiance calibration is critical with spectral calibration being less critical due to the broad-band features considered	Medium
Aerosol optical properties	This includes spectral extinction, absorption, phase function and shape (degree of sphericity)	Medium to high for sensors with low information content, low for AOD < 0.15
Vertical aerosol profile	Different assumptions are made for different aerosol types but sensitivity at TOA is small for VIS/IR sensors, increasing in the TIR	Medium for UV observations and absorbing aerosol, low otherwise
Directional reflectance ratio	Ratio between nadir and forward views is transferred from mid-infrared to visible bands	Medium for multi-view sensors
Pixel size	Ranges from 1x1 km^2 for radiometers to 16x7 km^2 for polarization instruments to approximately 0.25x0.5˚ for spectrometers	Medium when pixels dimension approach 50 km (approximate scale of aerosol variation)
Temperature vertical profiles	Usually of very high accuracy and precision, but might be significantly affected by the presence of high absorbing aerosol load	Low to medium (only for TIR sensors)
Trace gas concentration profiles	Critical absorption bands are usually avoided	Low
Radiative transfer forward model	Typical accuracy < 1%	Low
Look-up table discretization	Uncertainty often a function of the number of discretization points	Low
Wind speed	Used to estimate ocean reflectance	Low
Sampling	Practically all sensors under-sample the aerosol fields in time; different samplings lead to bias between different products	Depends strongly on the repeat cycle of the sensor and its swath width
Aggregation to 10x10 km^2	Aims to improve the signal-to-noise ratio and exclude outliers	Reduces random error (but not systematic) and may decrease representivity of data

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Uncertainties

On pixel-level (dominant terms)

$$\sigma_{AOD} = \sqrt{\left(\frac{\partial AOD}{\partial R_{TOA}}\ \sigma R_{TOA}\right)^2 + \left(\frac{\partial AOD}{\partial Alb_{surf}}\ \sigma Alb_{surf}\right)^2 + \left(\sigma_{AOD}^{ensemble}\right)^2 + \sigma^2(0)}$$

On aggregated levels (to be analysed)

- trace gas absorption correction
- altitude dependent Rayleigh scattering correction
- vertical layering of AOD
- look-up table error versus full radiative transfer calculations
- interpolation errors between the distinct angular values
- interpolation values between the distinct aerosol types

- Consider correlation structures of lv1 and auxiliary error propagation

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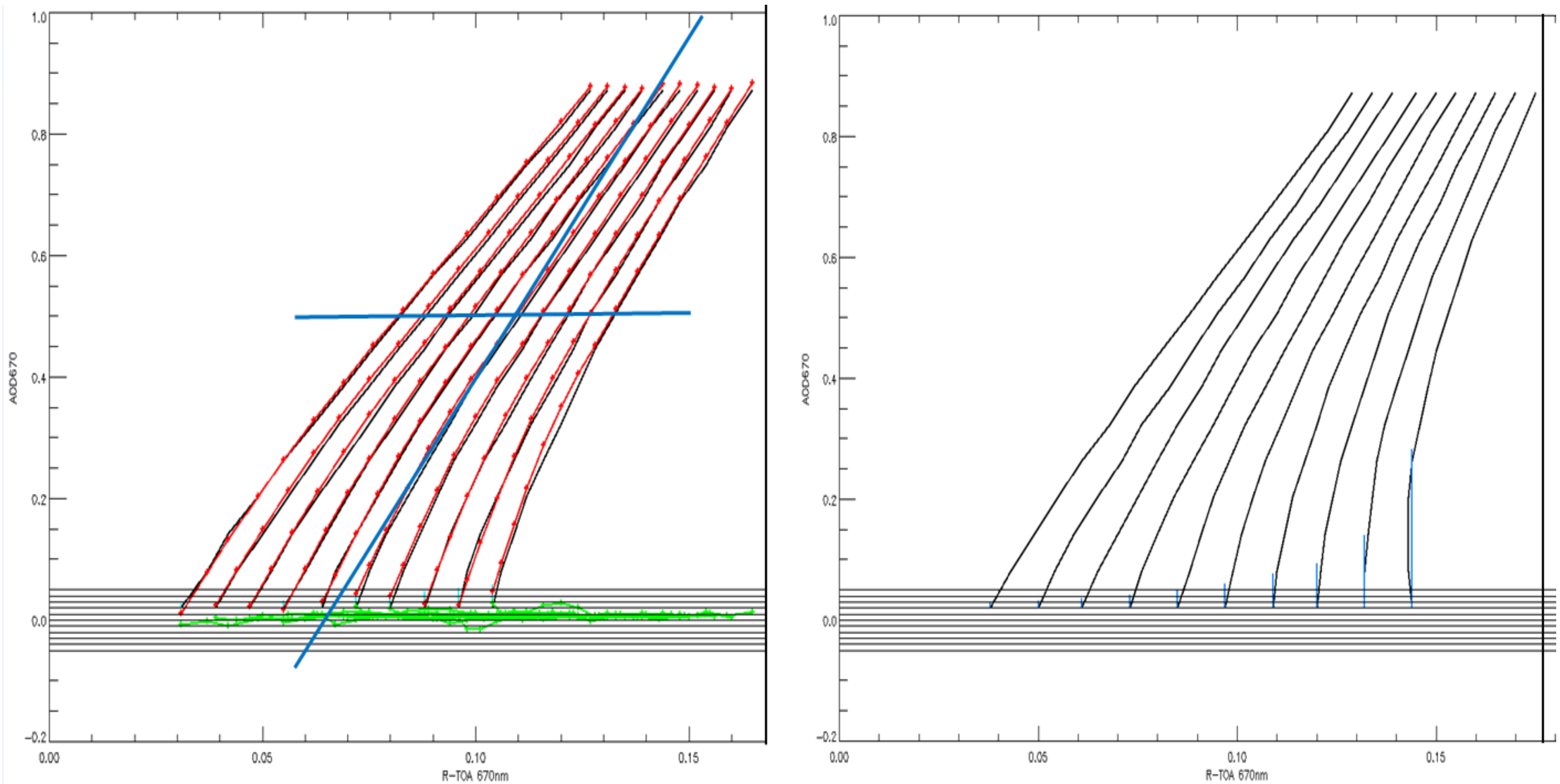
Aerosol sensitivity

Aerosol sensitivity depends on geometry, AOD, aerosol type

Low sensitivity cases need to be excluded / weighted



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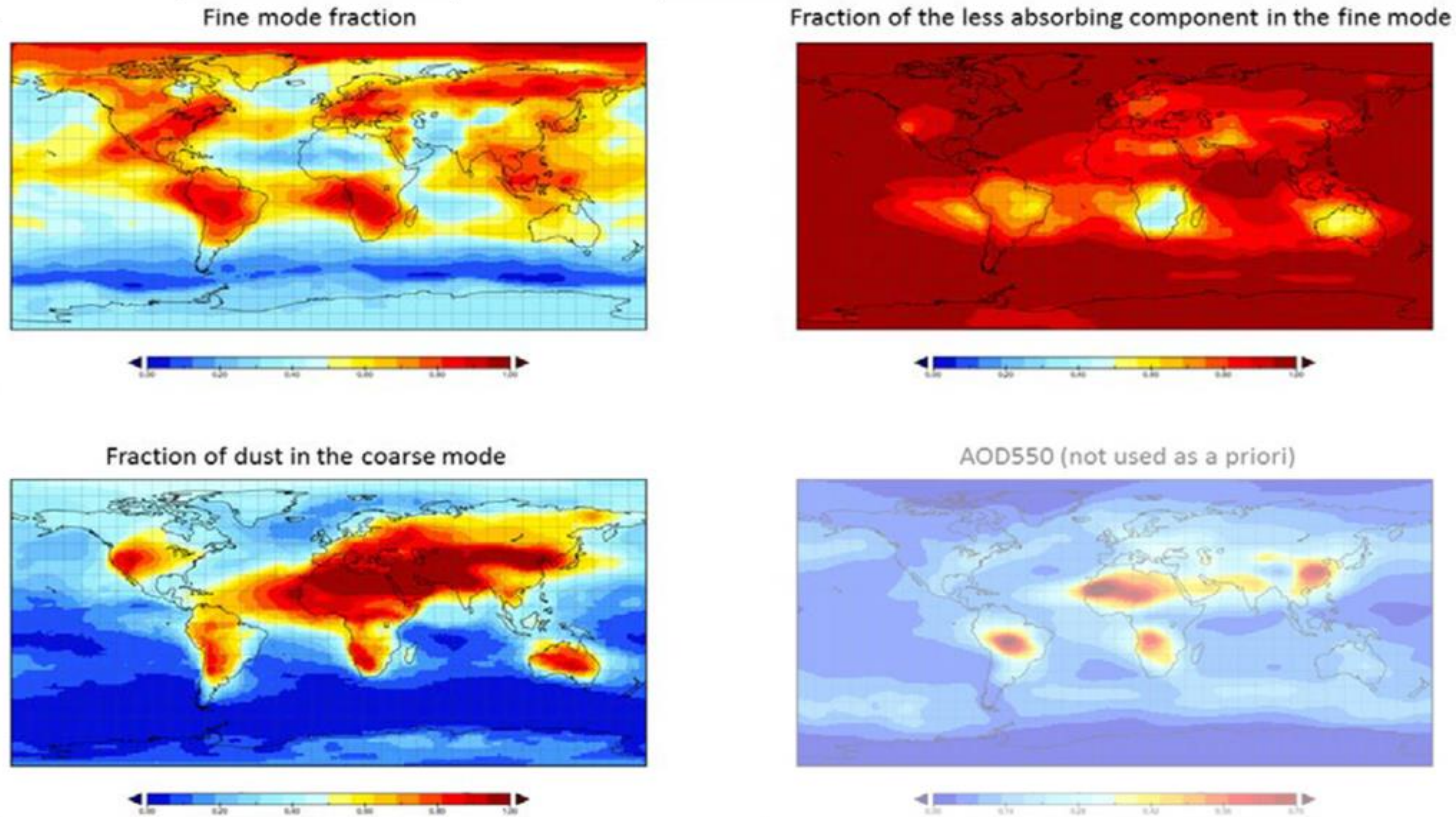
Aerosol type ensemble

Ensemble of mixtures of 4 “extreme” components

Defined by AERONET (optical properties) and AEROCOM model median



Ensemble of different aerosol mixtures

	All fractions are for AOD at 550 nm			
Mix no.	(FMWA+FMSA)/ (FMWA+FMSA+SALT+DUST)	FMWA / (FMWA+FMSA)	SALT / (SALT+DUST)	**Layer (km)**
1	1	1	-	0-2
2	1	0.88	-	0-2
3	1	0.77	-	0-2
4	1	0.66	-	0-2
5	1	0.55	-	0-2
6	1	0.44	-	0-2
7	1	0.33	-	0-2
8	1	0.22	-	0-2
9	1	0.11	-	0-2
10	1	0	-	0-2
11-20	0.8	as 1-10	0	0-2
21-30	0.8	as 1-10	0.5	0-2
31-40	0.8	as 1-10	1	0-2
41-50	0.6	as 1-10	0	0-2
51-60	0.6	as 1-10	0.5	0-2
61-70	0.6	as 1-10	1	0-2
71-80	0.4	as 1-10	0	2-4
81-90	0.4	as 1-10	0.5	0-2
91-100	0.4	as 1-10	1	0-1
101-110	0.2	as 1-10	0	2-4
111-120	0.2	as 1-10	0.5	0-2
121-130	0.2	as 1-10	1	0-1

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Timeline

AVHRR aerosol CDR

- Task starts 3/2017
- CDR delivery 6/2018
- Validation with AERONET 10/2018
- Comparison to SEVIRI AOD 10/2018
- 2nd FIDUCEO aerosol product from MVIRI: also benefits from collaboration

Benefit from FIDUCEO

- Use FCDR lv1 uncertainties
- Consider correlations (main classes)
- Improve lv2-lv3 uncertainty characterization
- Pragmatic solutions (limitations of runtime, auxiliary knowledge)
- Focus on dominant uncertainty sources (on all scales)

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Common interest with GAIA-CLIM and AEROSAT

AOD validation itself

- Is done with AERONET (low uncertainty)

Better characterisation of aerosol type uncertainties

- Comparison to lidar aerosol type information
- Evaluate impact on retrieved AOD of assumptions on aerosol type
- Help to optimize the ensemble definition
    - Appropriate variance in model ensemble

Robust correction of overlap issue in lidar – satellite (column) comparisons

Contribute to AEROSAT (consistent nomenclature)

Develop uncertainty methodology further for aerosol retrieval community

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