Future needs for aerosols

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Acknowledgments: LOA and ICARE Colleagues + collaborators.

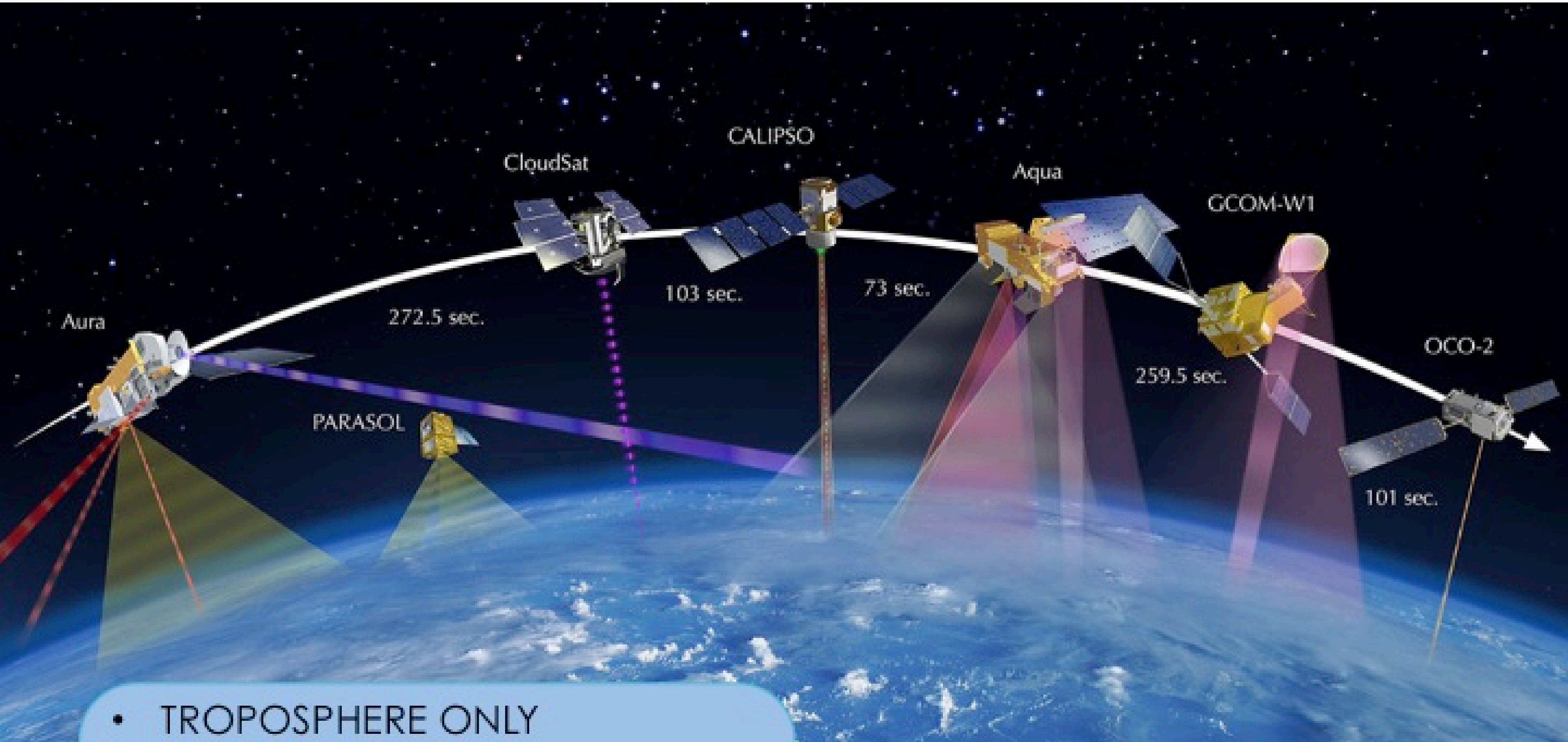
OUTLINE

- Highlights linked to synergetic analyses of A-Train.
- Illustration of major inputs with regard to model needs.
- Gaps/Needs.

A-TRAIN

RELEVANT INSTRUMENTS FOR AEROSOL STUDIES USED IN THIS PRESENTATION:

AQUA: CERES/MODIS **CALIPSO: CALIOP** **PARASOL: POLDER**



- TROPOSPHERE ONLY
- Solar Spectrum

ILLUSTRATION: Aerosol Direct Radiative Effect

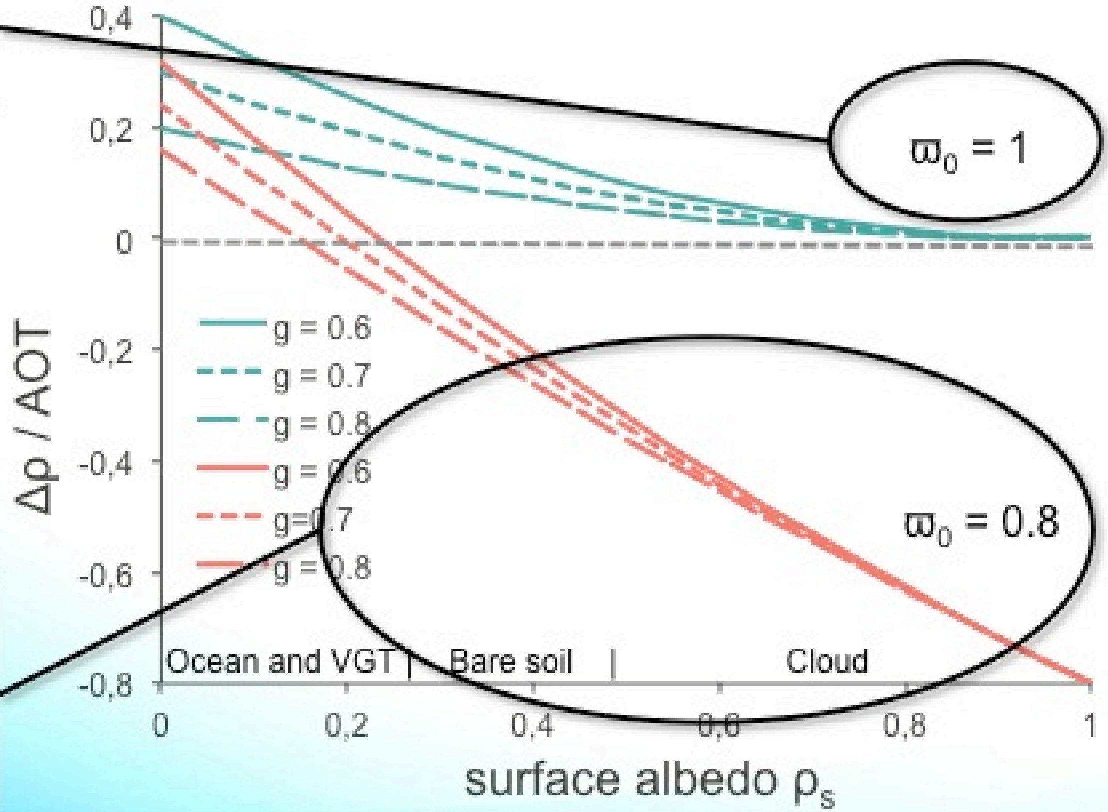
Non-Absorbing aerosols : increase of the local planetary albedo = cooling effect

Perturbation of the albedo of a scene ($\Delta\rho$) by a thin aerosol layer vs. the surface albedo ρ_S (per unit of AOT)

ϖ_0 : aerosol single scattering albedo

g : asymmetry parameter

Absorbing aerosols above bright surfaces or clouds : reduction of the local planetary albedo = warming effect



$$\Delta\rho = \rho - \rho_s = aot.\left(\varpi_0.(1-g).(1-\rho_s)^2 - 4.(1-\varpi_0).\rho_s\right)$$

(Lenoble et al., JAS, 1982)

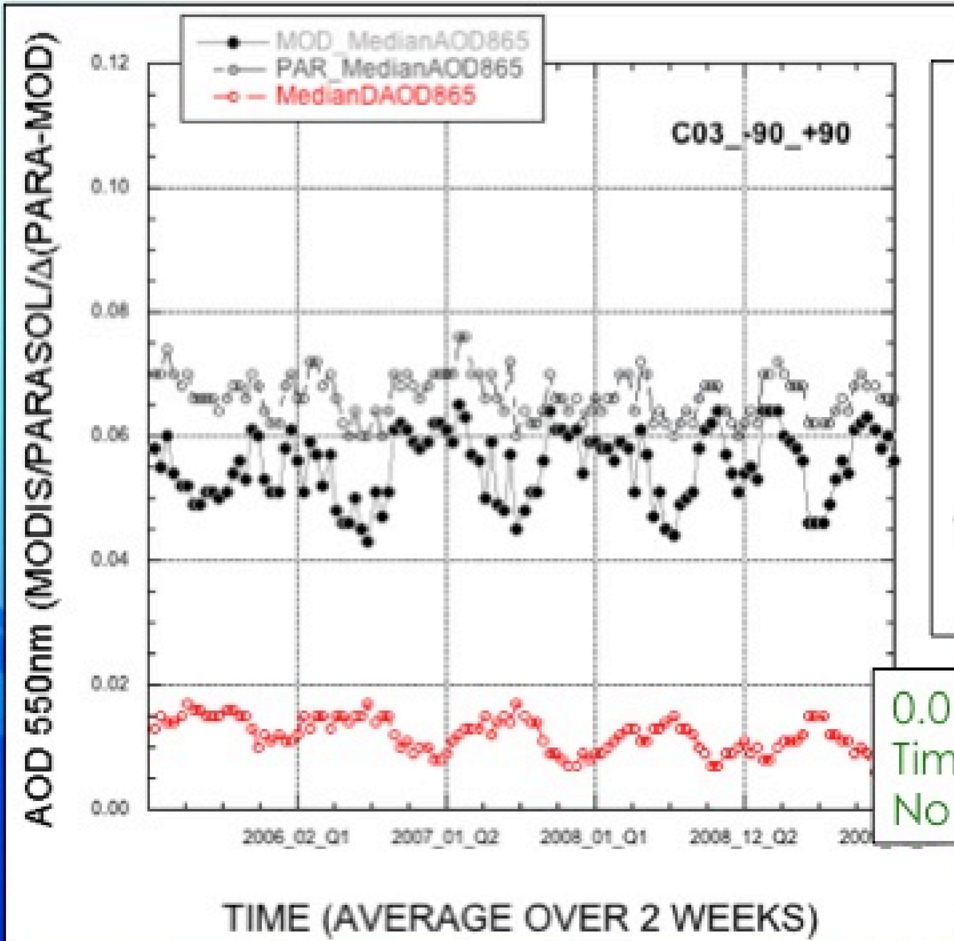
Aerosol Direct Radiative Effect

- CLOUD-FREE SKY:
  - « Accurate » aerosol retrievals from passive instruments are limited to observations over ocean.
  - Difficult at global scale over land (bright surfaces) using passive observations (need assumptions regarding aerosol models and/or surface properties)

- CLOUDY SKY:
  - Active sensors are more suitable
  - Current passive methods are limited and require constraints on aerosol models

Aerosol Direct Radiative Effect (cloud-free sky)

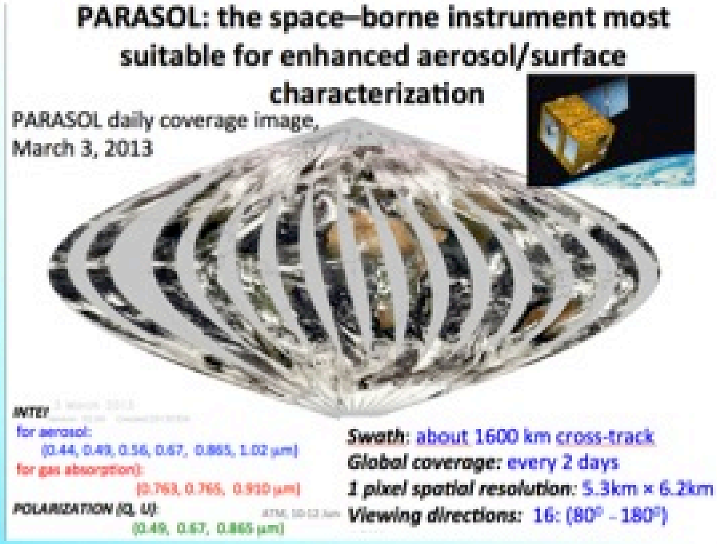
OVER OCEAN



Satellite intercomparison provide a robust way to test for unanticipated retrieval error (Calibration/ Algorithms/cloud contamination): MODIS C06 & PARASOL C03

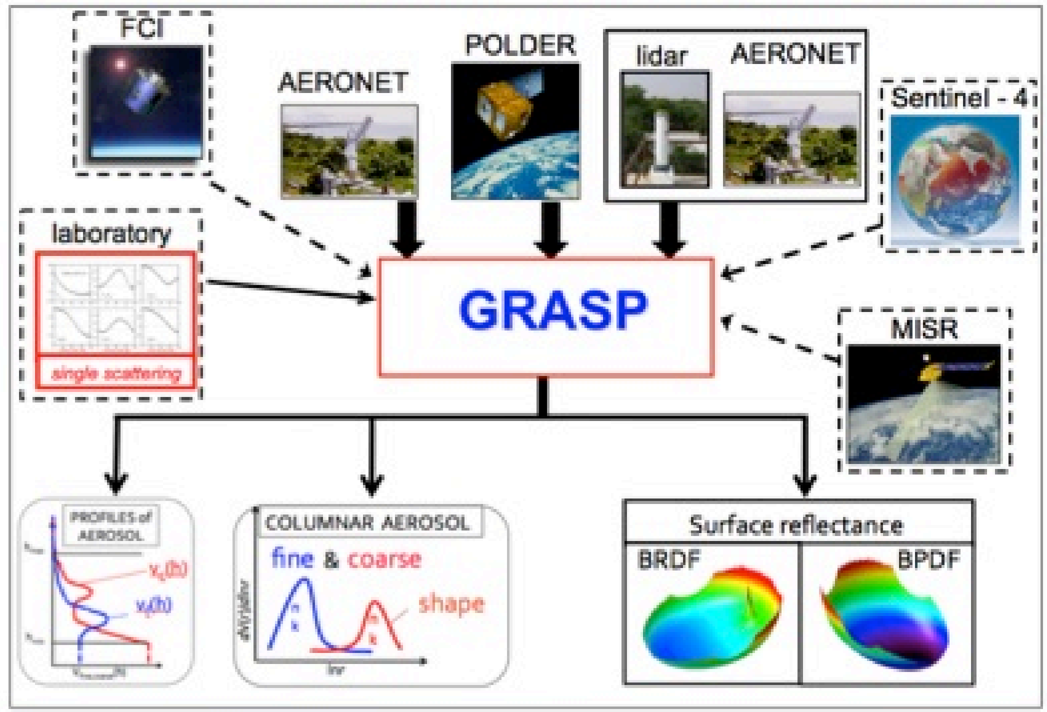
0.010 +/-0.005
Time dependence
No trend

Aerosol Direct Radiative Effect (cloud-free sky)



Dubovik et al., 2011, 2014

GRASP: Generalized Retrieval of Aerosol and Surface Properties



- Concept of multi-pixel retrieval
- Surface+aerosols are retrieved at the same time
- Detailed aerosol informations (size distribution, absorption, chemical composition, aerosol height)
- Retrieval use practically no information about surface and type of aerosol.

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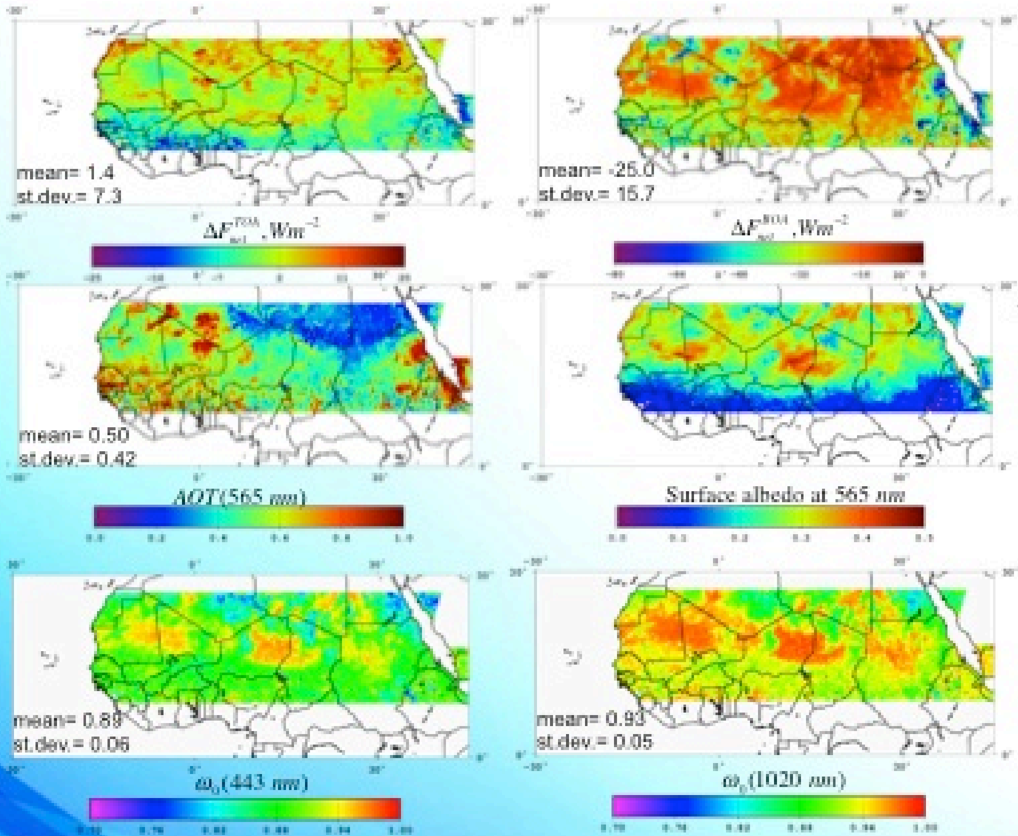
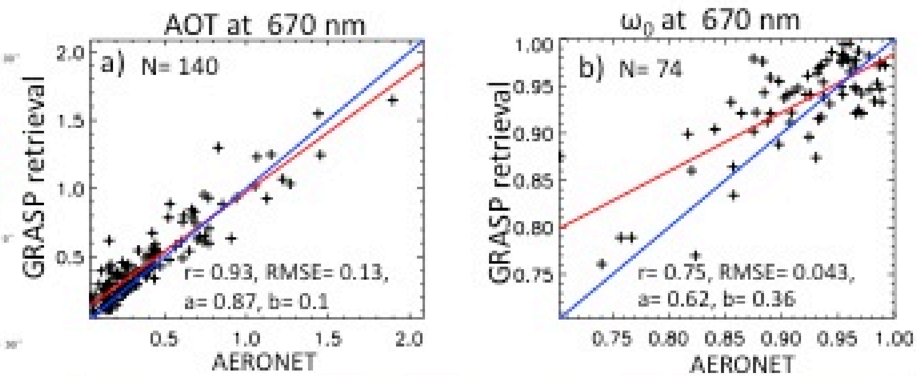
Aerosol Direct Radiative Effect (cloud-free sky)



Three-month (JJA 2008) means of top and bottom-of-atmosphere (TOA and BOA) 24 h average net aerosol radiative effect (top), AOT at 565 nm, underlying surface albedo at 565 nm (middle) and ω_0 at 443 nm and 1020nm (bottom). The panels include the domain averages and corresponding standard deviations

Derimian et al., ACP, 2016



Intercomparison between GRASP retrievals applied for POLDER/PARASOL observations and AERONET products during 2008 for observations at four sites (Banizoumbou, Agoufou, IER Cinzana and DMN Maine Soroa).

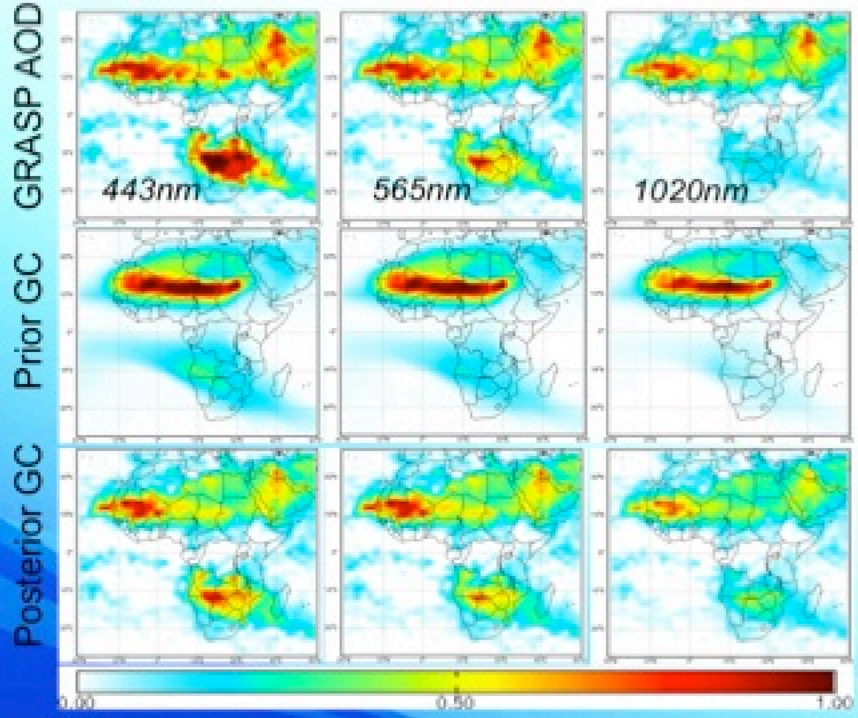
$$F^0_{\uparrow TOA} - F^a_{\uparrow TOA}$$

$$\Delta F^{Net}_{BOA} = \left(F^a_{\downarrow BOA} - F^a_{\uparrow BOA}\right) - \left(F^0_{\downarrow BOA} - F^0_{\uparrow BOA}\right)$$

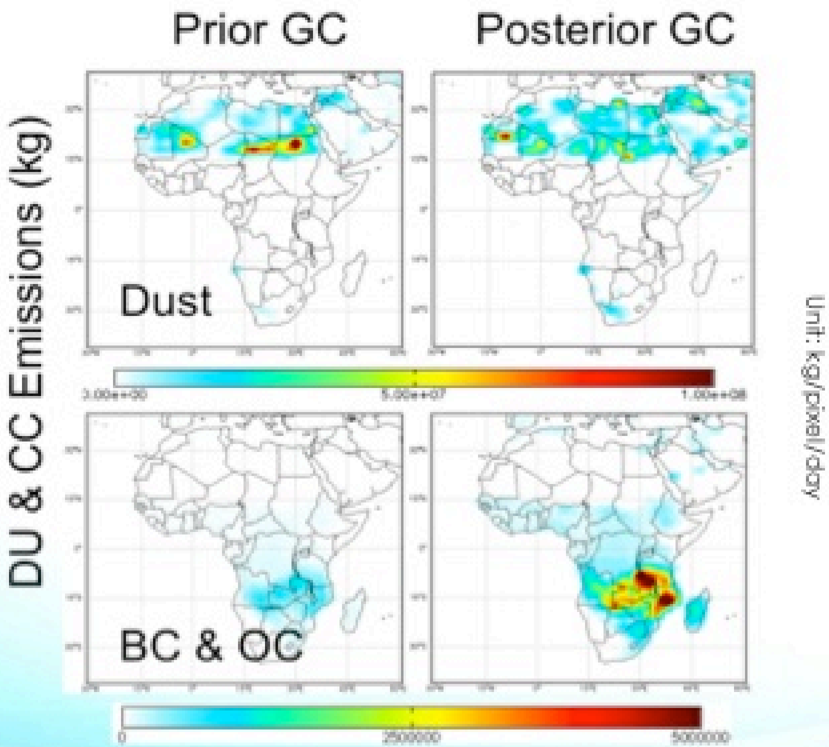
Aerosol Sources: Enhancement of Models

Chen, Dubovik et al., in preparation.

The results of inversion of ~ 2 week (September/ October 2008). Average AODs: upper panel – **PARASOL AOD'S** retrieved by GRASP; middle panel - predicted by GEOS-CHEM; lower panel - obtained from GEOS-CHEM using corrected Dust, BC and OC emissions.



The right part compares default **GEOS-CHEM emissions** denoted as "Prior" with retrieved denoted as "Posterior".

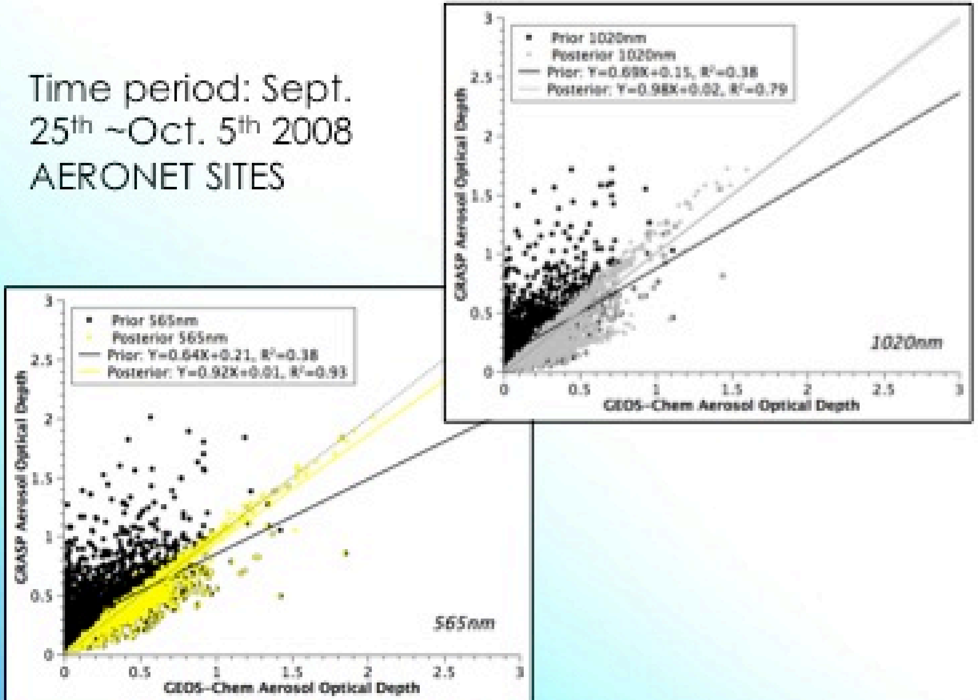


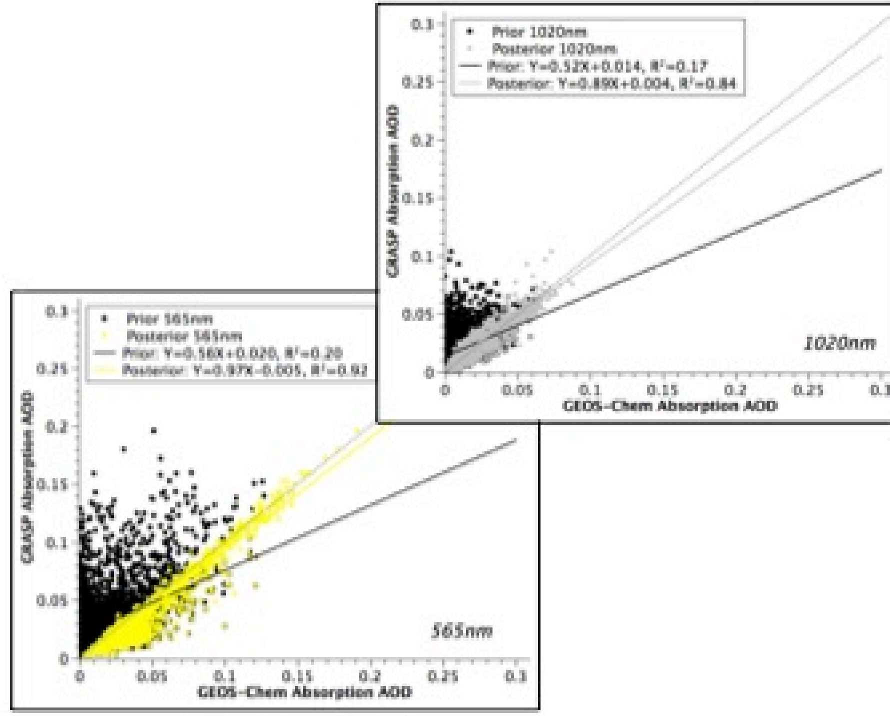
"Posterior" aerosol distribution of AOD based on corrected emission agrees much better with "Prior" aerosol distribution of AOD based on sourced used in GEOS-CHEM by default. It is clear from the figure that default GEOS-CHEM emissions strongly underestimated BC and OC emissions and overestimated dust emissions.

Aerosol Sources: Enhancement of Models

Chen, Dubovik et al., in preparation.

Time period: Sept. 25th ~Oct. 5th 2008
AERONET SITES





AOD AERONET/GEOS-Chem

Wavelength (nm)	Prior			Posterior		
	slope	intercept	R^2	slope	intercept	R^2
443	0.66	0.26	0.33	1.00	0.01	0.86
490	0.64	0.24	0.35	0.95	0.02	0.90
565	0.64	0.21	0.38	0.92	0.01	0.93
670	0.64	0.18	0.40	0.90	0.00	0.92
865	0.69	0.15	0.39	0.93	0.01	0.84
1020	0.74	0.13	0.38	0.98	0.01	0.79

Absorption AOD AERONET/GEOS-Chem

Wavelength (nm)	Prior			Posterior		
	slope	intercept	R^2	slope	intercept	R^2
443	0.56	0.024	0.19	1.00	-0.011	0.90
490	0.55	0.022	0.19	0.97	-0.008	0.91
565	0.56	0.020	0.20	0.97	-0.005	0.92
670	0.60	0.018	0.20	0.96	-0.001	0.93
865	0.57	0.015	0.19	0.91	0.004	0.88
1020	0.53	0.014	0.17	0.89	0.004	0.84

Aerosol Direct Radiative Effect (cloudy sky)

Current methods to retrieve aerosol properties above clouds

	Input parameters	Retrieved parameters
CALIOP Operational method (Winker et al., 2009; Young and Vaughan, 2009)	Attenuated backscatter profile at 532 and 1064 nm	AOT
CALIOP Depolarization method (Hu et al., 2007)	Layer integrated attenuated backscatter profile, depolarization ratio at 532 nm	AOT and angström exponent
CALIOP Color ratio method (Chand et al., 2008)	Layer integrated attenuated backscatter, color ratio	AOT and angström exponent
OMI (Torres et al., 2012)	Reflectance at 388 nm, measured UVAI	AOT and COT (aerosol models assumed)
MODIS color ratio (Jethva et al., 2013)	Reflectance at 470 and 860 nm	AOT, COT (aerosol models assumed)
MODIS (Meyer et al., 2015)	Reflectance at 470, 550, 660, 860, 1240 and 2100 nm	AOT, COT and r_{eff} (aerosol models assumed)

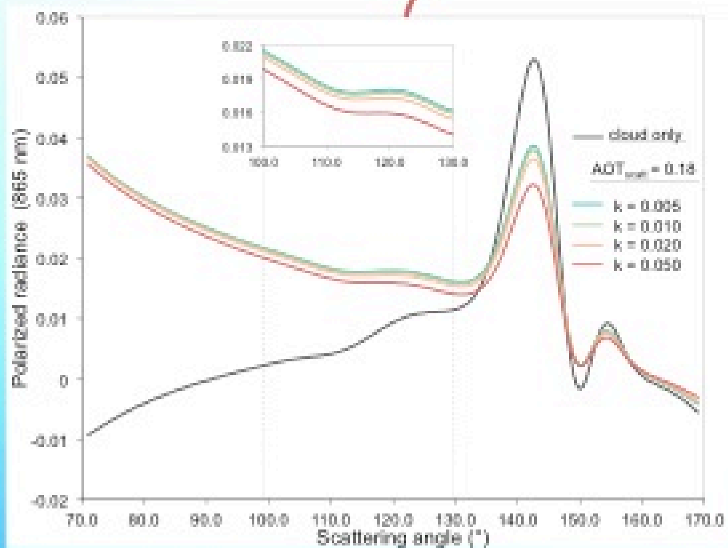
Need to use passive sensors for getting a better spatial coverage than active sensors but with no assumptions regarding the aerosol model.

(from Peers, 2015)

Aerosol Direct Radiative Effect (cloudy sky)

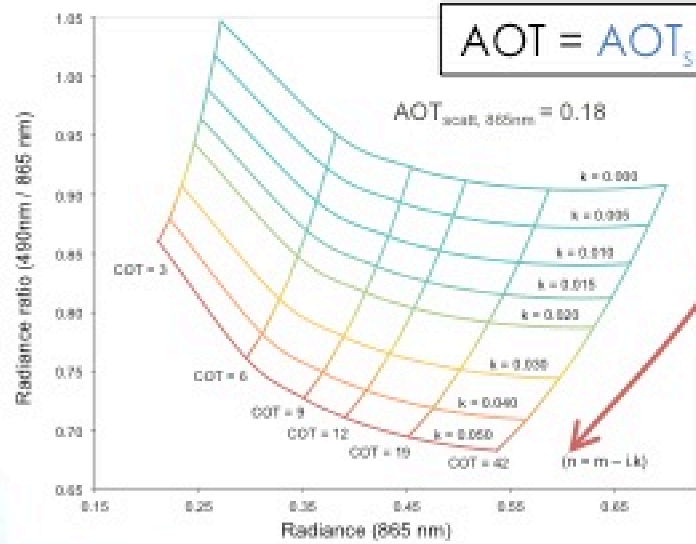
Waquet et al., JAS, 2009, AMT, 2013

Peers et al., ACP, 2015



the scattering AOT is set

$AOT = AOT_{scatt} + AOT_{abs}(k)$



increasing k = increasing of the aerosol absorption

- Polarized radiances are mostly sensitive to scattering processes.
- Cloud + fine mode aerosol *(r_{eff} = 0.1 μm)*: Additional polarization at side scattering angle

Radiances at 490 and 865 nm can be interpreted as a coupled COT and absorption AOT since the scattering optical thickness of aerosol and their size are known.

Aerosol Direct Radiative Effect (cloudy sky)

PARASOL methods to retrieve aerosol properties above clouds

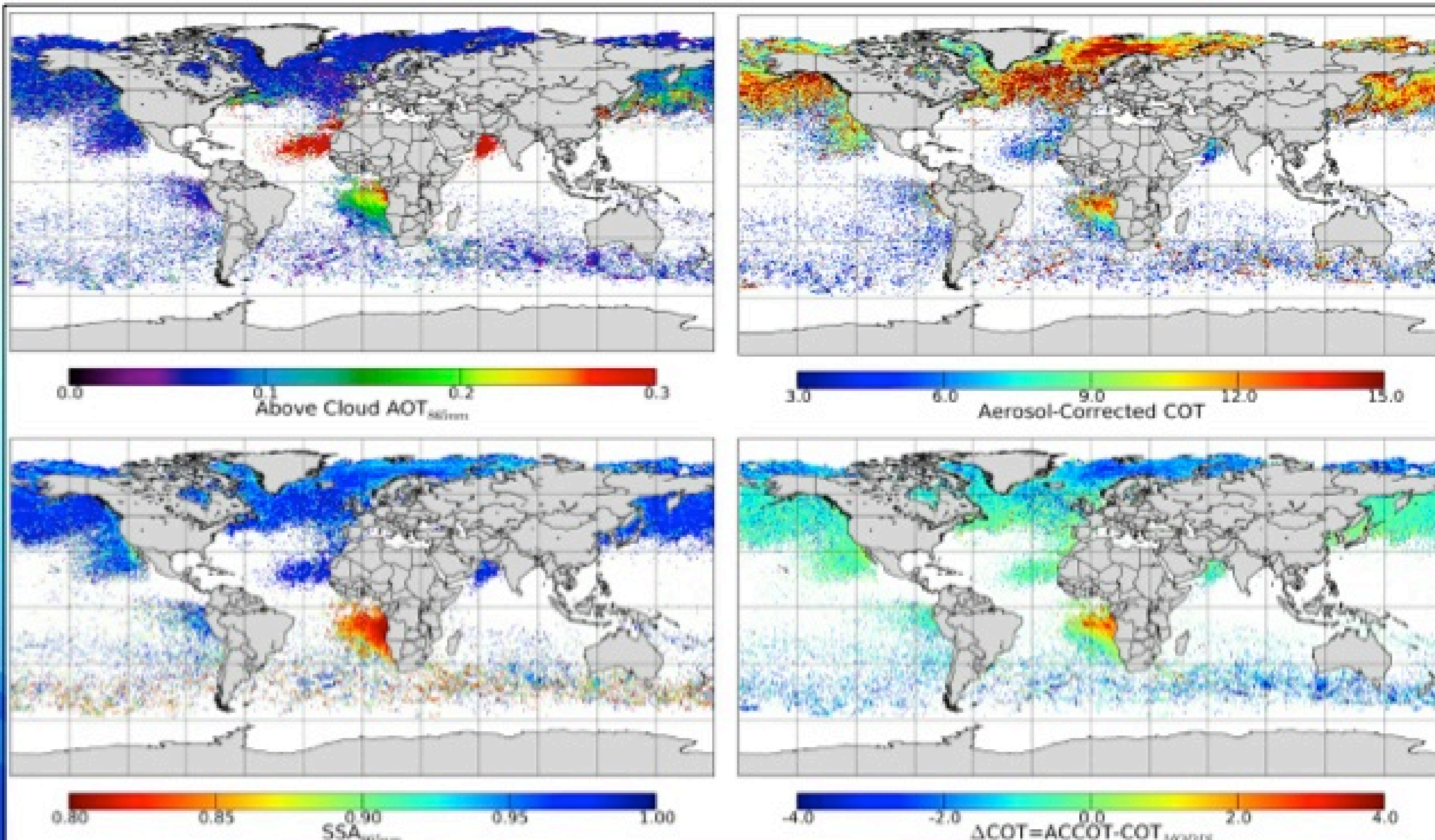
	Input parameters	Retrieved parameters
CALIOP Operational method (Winker et al., 2009; Young and	Attenuated backscatter profile at 532 and 1064 nm	AOT

	Input parameters	Retrieved parameters
• Liquid clouds with no cirrus above • COT>3 (Cloud polarized radiances don't depend on COT)	• POLDER polarized and total radiances, COT, CTH, cloud phase; • r_{eff} ,cloud phase, cloud mask (from MODIS); • Ozone, water vapor content (meteorological reanalysis)	• AOT, • Size/AE (several angstrom exponents) • SSA (presently over ocean) • Corrected MODIS COT

MODIS color ratio (Jethva et al., 2013)	Reflectance at 470 and 860 nm	AOT, COT (aerosol models assumed)
MODIS (Meyer et al., 2015)	Reflectance at 470, 550, 660, 860, 1240 and 2100 nm	AOT, COT and r_{eff} (aerosol models assumed)

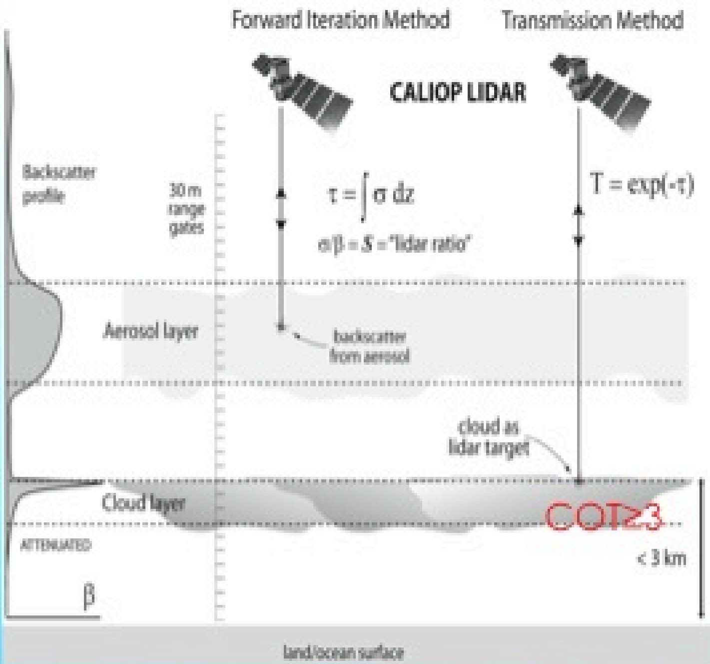
Aerosol Direct Radiative Effect (cloudy sky)

Waquet et al., GRL, 2013



Aerosol and cloud retrieved properties for aerosols above clouds scenes with POLDER/ PARASOL (June to August 2008)

Aerosol Direct Radiative Effect (cloudy sky)



<u>Comparison/Validation</u>: CALIOP Depolarization Ratio Method

Approach :
- Opaque cloud as target (**COT≥3**) : lidar beam completely attenuated
- Estimates AOT from the transmission (using the Beer-Lambert law after molecular/gas corrections)

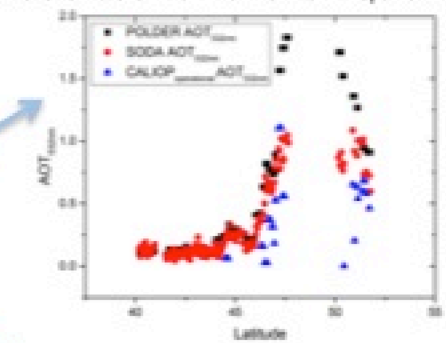
Data :
- integrated attenuated backscatter γ ' of cloud layer
- Integrated depolarization δ ' of cloud layer

Pros/Cons :

\+ No assumption on aerosol microphysics

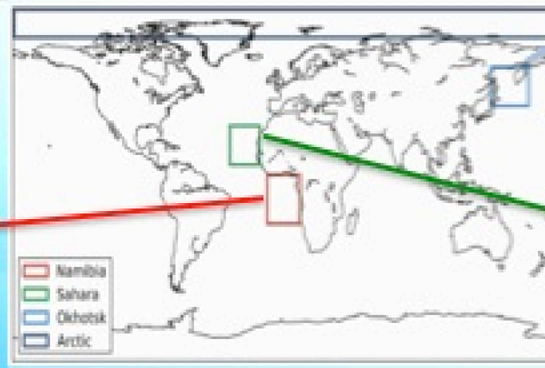
\- Sensitive to calibration and potentially to cloud heterogeneities

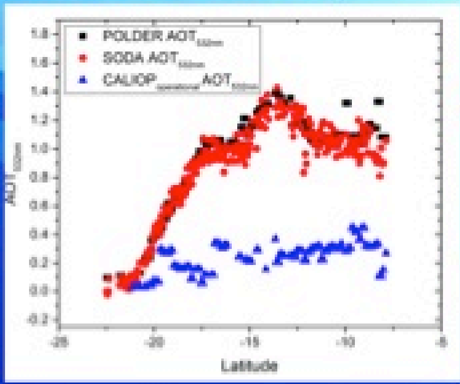
\- Assumption: layer extinction-to-backscatter ratio for liquid water clouds Sc=19sr (Mie code)



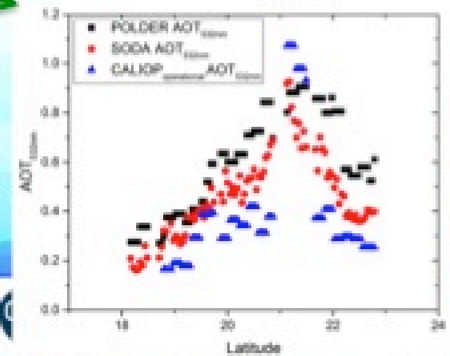
CALIOP: V3.01

SODA(V2.00): Synergized Optical Depth of Aerosols; Josset et al, 2012)





Deaconu, Waquet, et al., in preparation

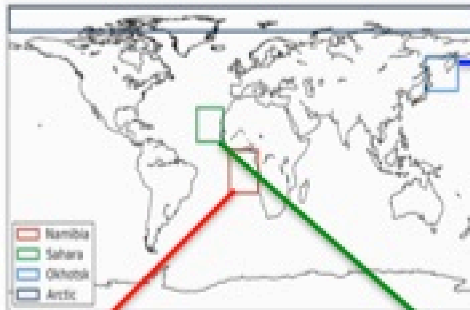


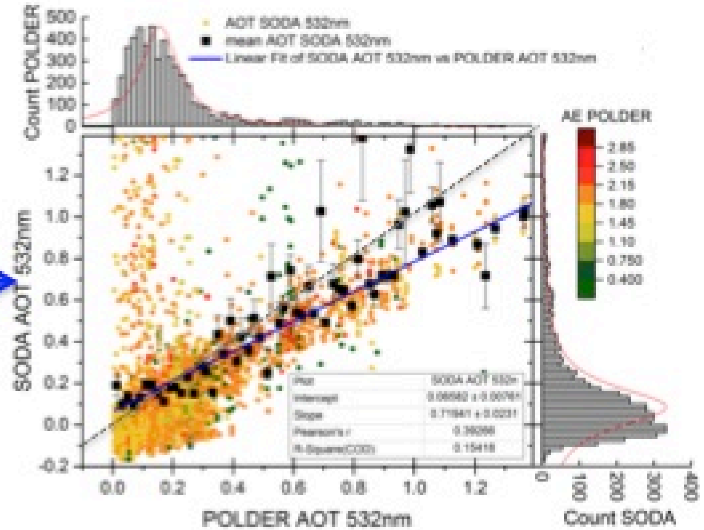
Aerosol Direct Radiative Effect (cloudy sky)

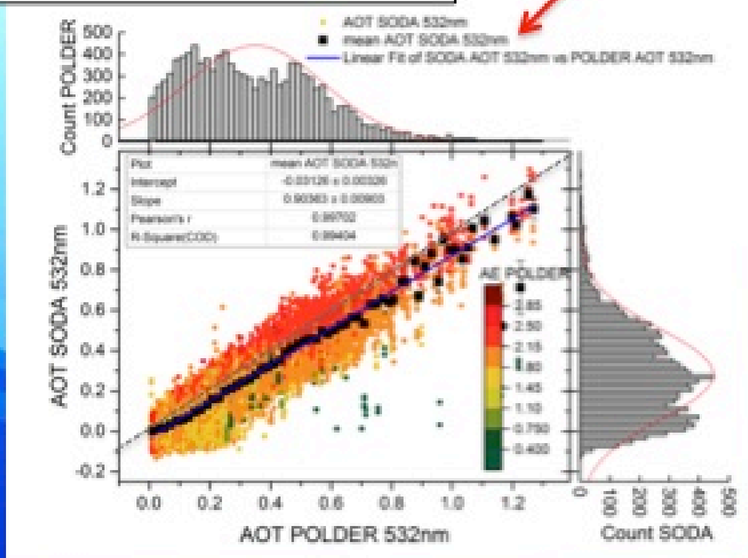
Comparison with CALIOP : Regional analysis
6 months: May->October 2008

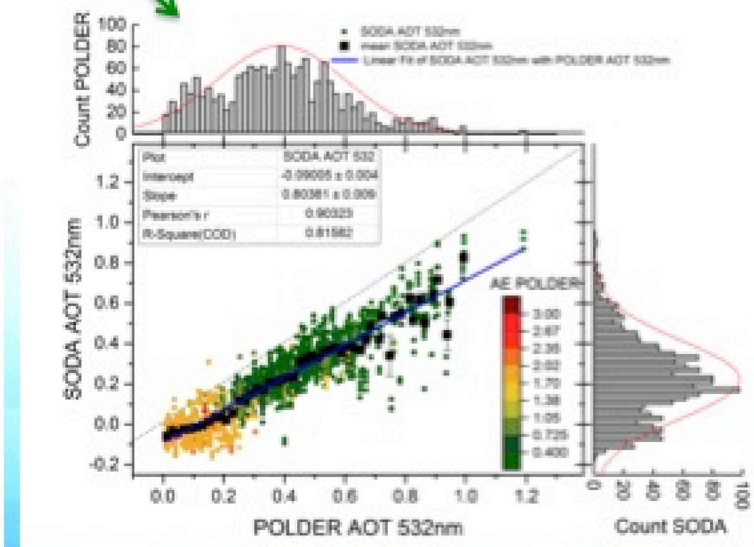
Deaconu, Waquet, et al., in preparation

- North Atlantic - coast of Namibia – biomass burning events: R^2=0.99
- South Atlantic - coast of Sahara – dust events: R^2=0.81
- Sea of Okhotsk (Asia) – mixture events: R^2=0.150





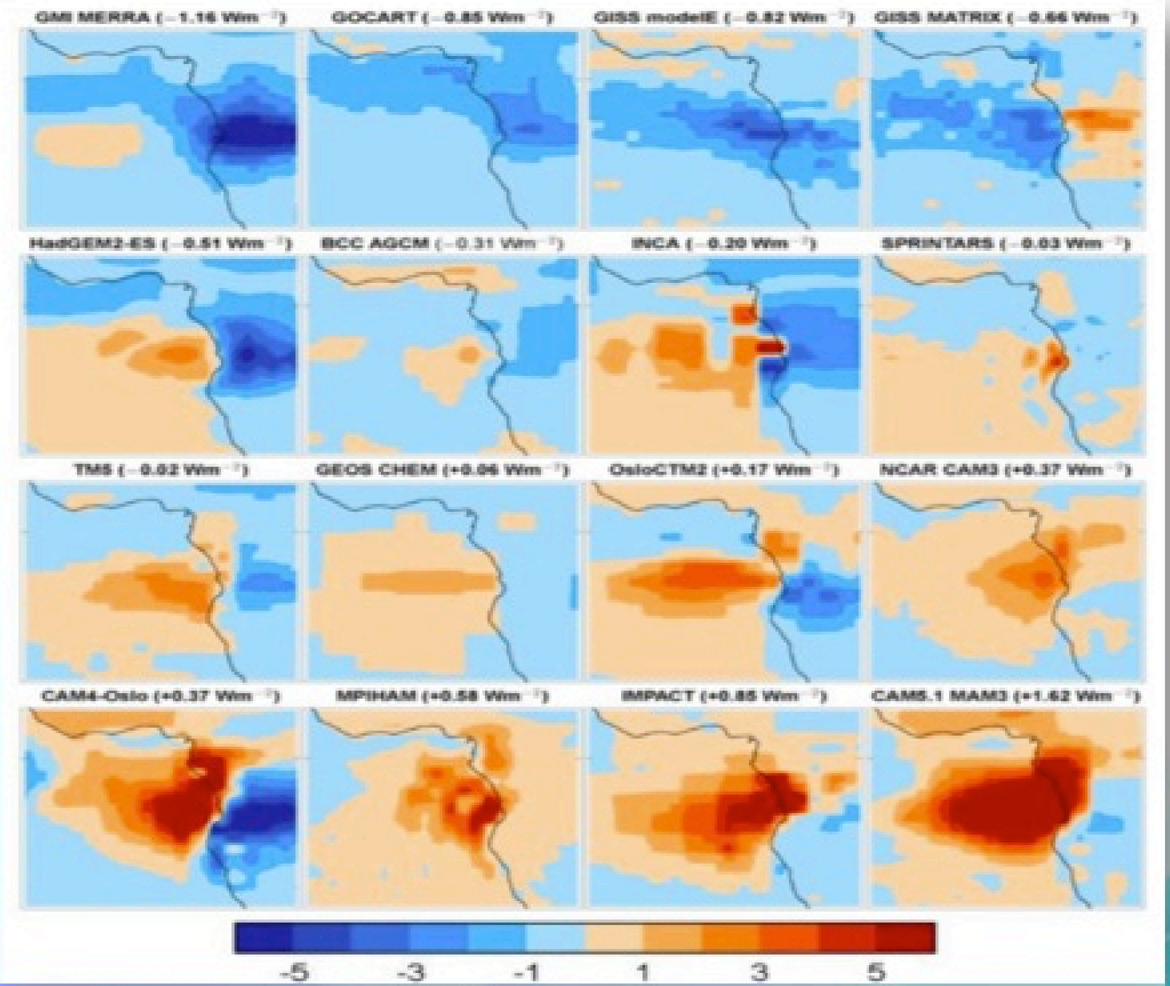




Aerosol Direct Radiative Effect (cloudy sky)

AeroCom Direct Radiative Effect of Aerosols – August-September ($W.m^{-2}$)

The direct radiative effects of aerosols in cloudy scenes is highly uncertain.



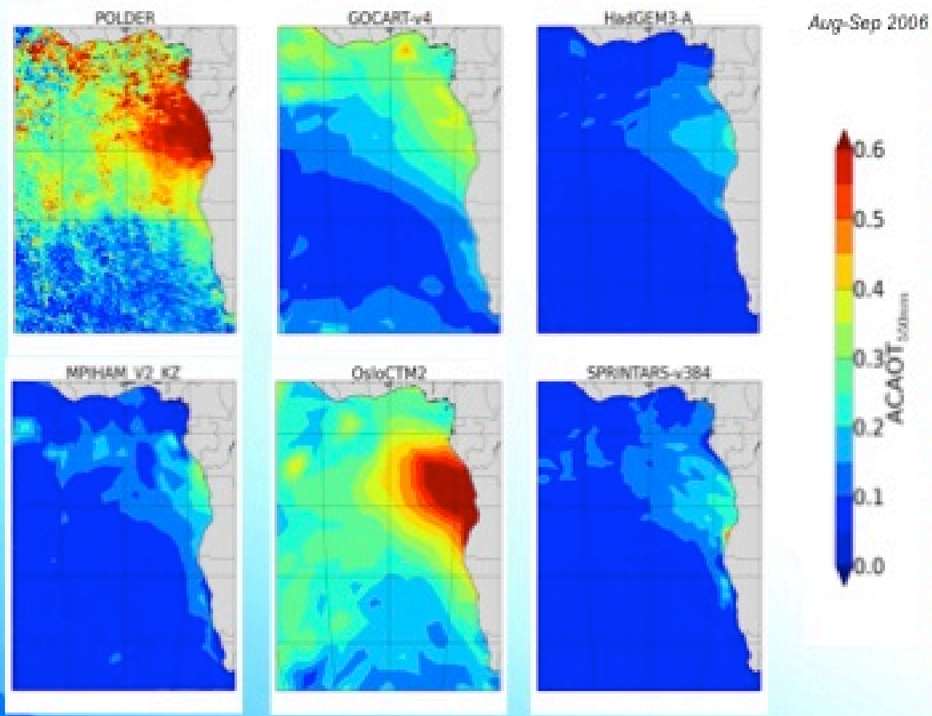
Need to better constrain aerosol and cloud properties in global aerosol models.

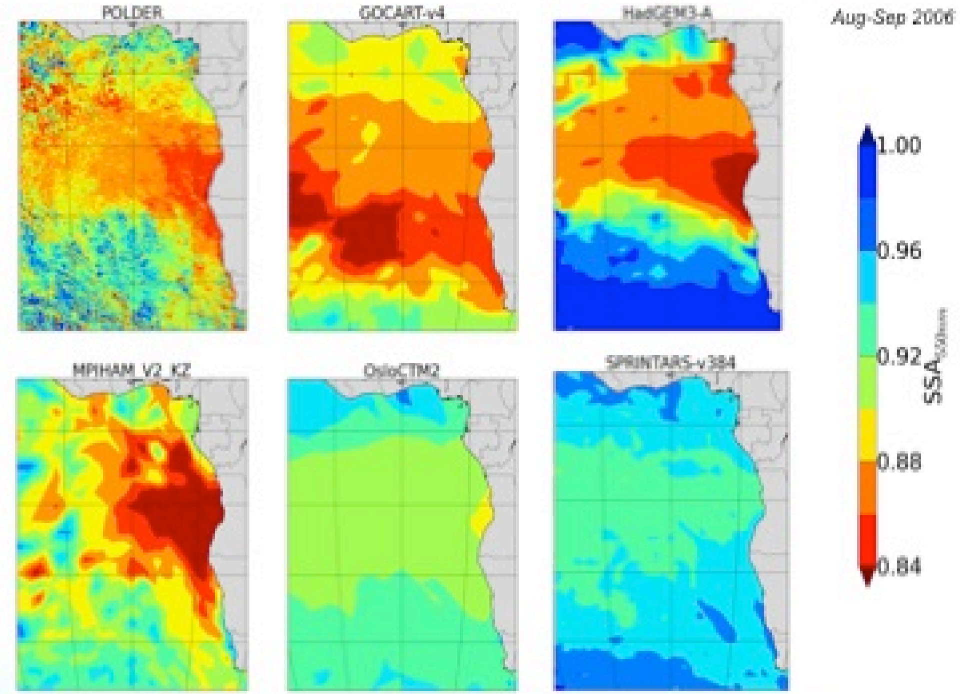
Aerosol Direct Radiative Effect (cloudy sky)

AOT_550 nm

Comparison with 5 AeroCom Models

SSA_550 nm





Injection height too low
(except OSLO: between 0 and 5km)

RI_{BC} : Black Carbon Refractive Index
$M_{BC/OA}$: Black Carbon to Organic Carbon column integrated ratio

HadGEM: RI_{BC} = 1.85 – 0.71x i
$M_{BC/OA}$ = 5.4 %

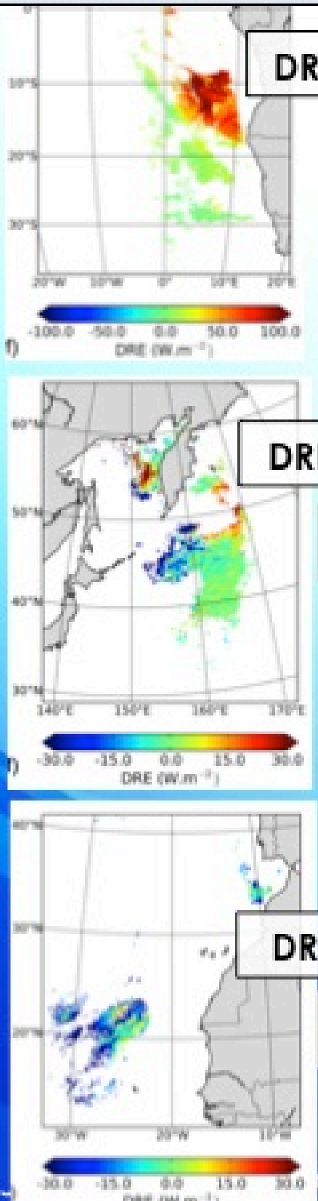
August-September 2006

(Peers et al., GRL, 2016)

Aerosol Direct Radiative Effect (cloudy sky)

(Peers et al., ACP, 2015)

(Peers et al., in preparation)



DRE = 36.5 $W.m^{-2}$

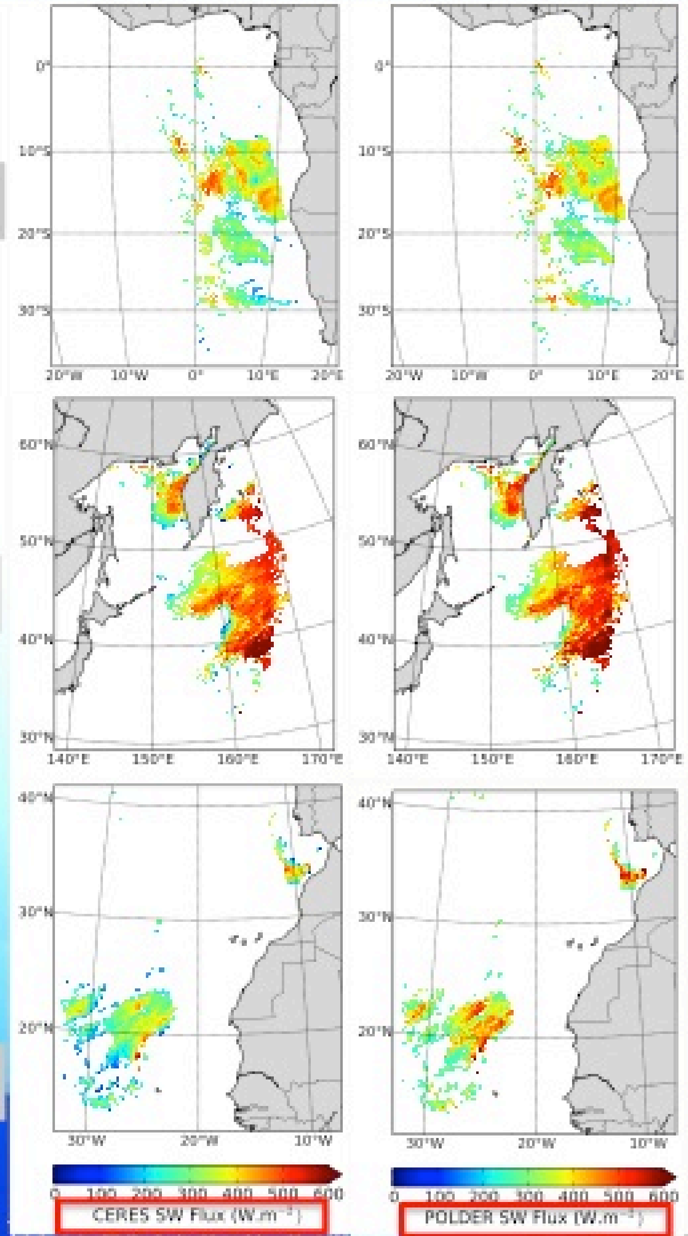
(04/08/2008)

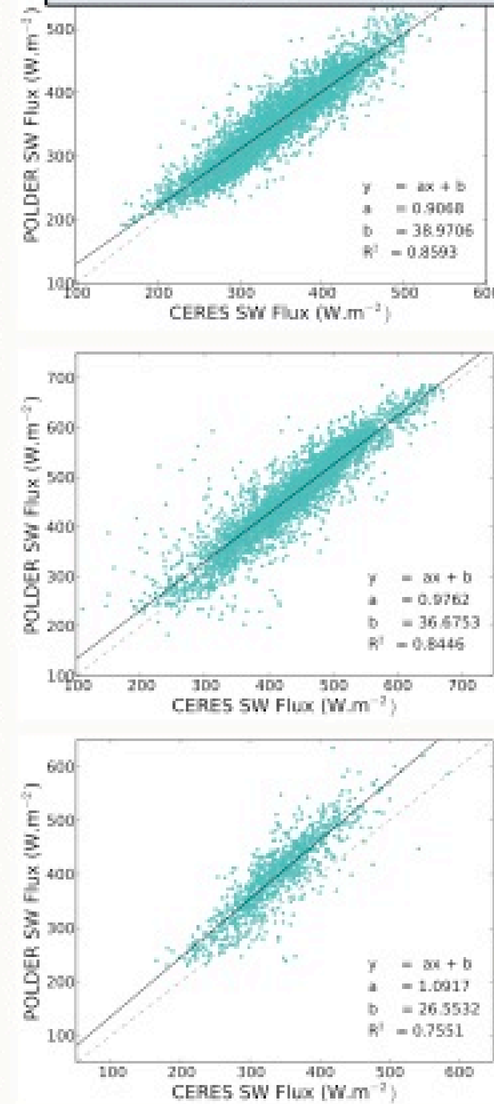
DRE = -3.5 $W.m^{-2}$

(03/07/2008)

DRE = -18.5 $W.m^{-2}$

(04/08/2008)





SUMMARY

A-TRAIN: state of the art of aerosol remote sensing

- The **Afternoon Constellation provides near-coincident, co-located observations** for instruments on different spacecrafts. Technical challenge to control the satellite's relative motion within the Afternoon Constellation.

- **« Total-column » aerosol optical properties (over ocean, land, clouds) are retrieved from passive multiangle, multispectral, and polarized imagers** associated to development of **new algorithms** (relevant for Direct and semi-direct aerosol radiative effect).

- **Active instruments** provide aerosol and cloud detailed vertical structure and **are critical for understanding and documenting cloud-aerosol interaction** (What happens to aerosol in the vicinity of clouds?)

- **Intercomparisons** provide a robust way to test for unanticipated retrieval error or to understand the limits of a specific scheme/or instrument.

- New algorithms can consider **several measurements (Level #1 data) in a single inversion** (synergetic active-passive retrievals).

GAPS/NEEDS

- There are **enhancement of aerosol and cloud measuring capabilities of several single sensors** (EUMETSAT Post_EPS, EarthCare, NPOESS).

- **Lack of satellite constellation** in Sun-synchronous orbits beyond A-train era when we need co-located observations as provided by the A-train.