Aerosol Optical Depth and Direct Aerosol Forcing using SEVIRI/GERB

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Earth Radiation Budget Workshop 2012
Geophysical Fluid Dynamics Laboratory
Princeton, NJ, 2012/10/25

Outline

Introduction

AOD over Ocean
- Algorithm
- Examples
- Validation Results

DAF over Ocean
- Algorithm
- Examples

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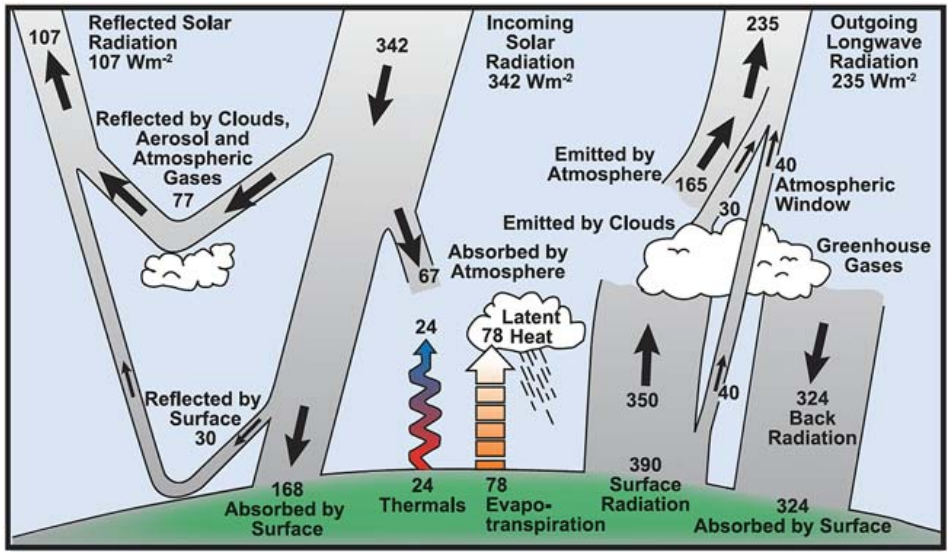
Motivation



- Generation of climate data record (CM-SAF)
- Time period: 2004 - end of MSG era
- Include in GERB radiance to fluxes processing

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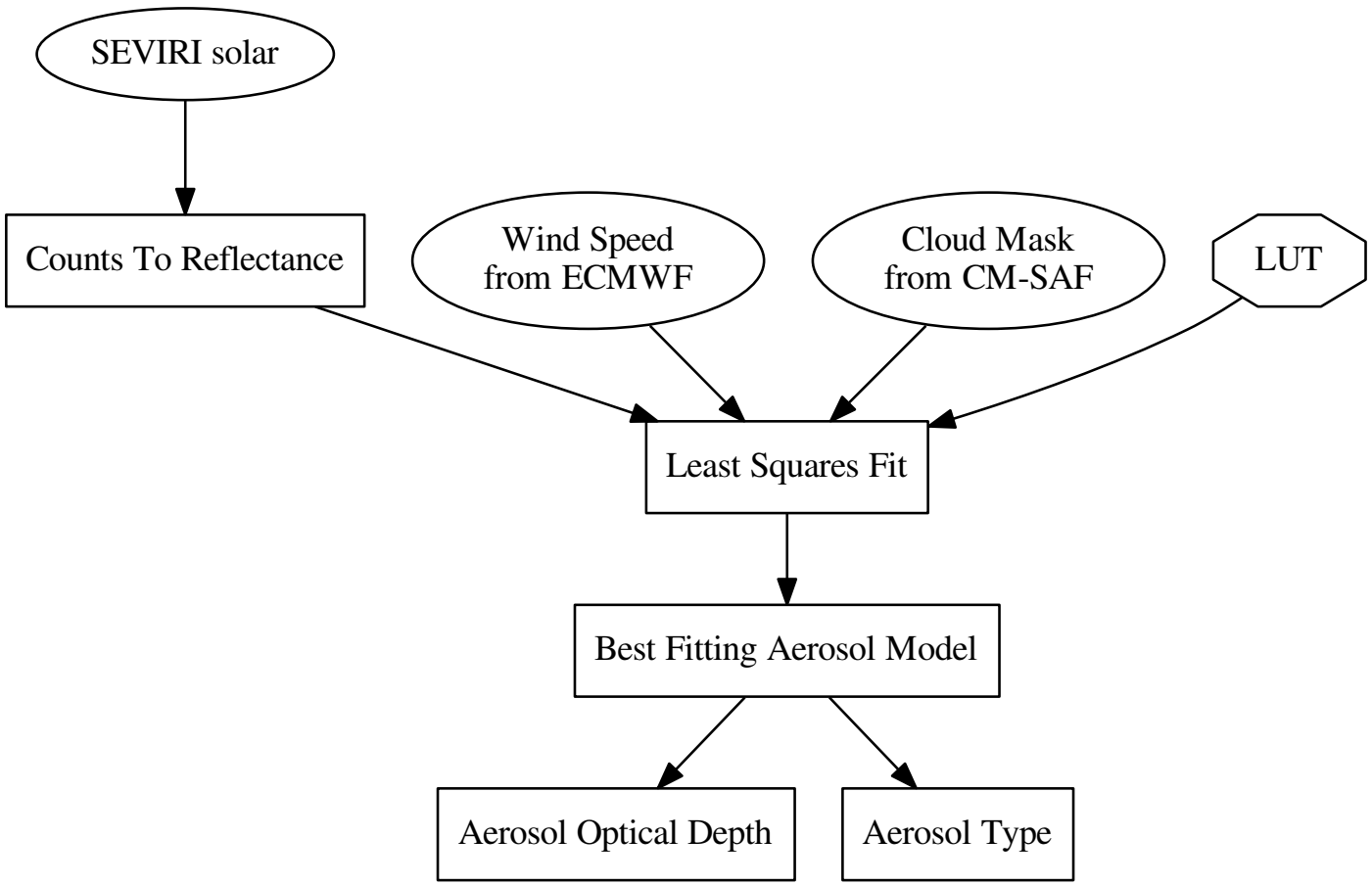
Flowchart of the Algorithm



Balloons represent on-line data, octagons off-line data and boxes methods.

Look Up Table

- TOA radiances computed with LibRadtran 1.6
- Radiative transfer solver = DISORT2 with 48 streams
- Ocean BRDF = Cox-Munk

  wind speeds: 2, 5, 10 and 15 m/s
- Aerosol types
  - 3 spherical and 3 non-spherical classes
  - taken from Govaerts et al. (2010)
  - derived from an analysis of AERONET retrieval.
- AOD at 550 nm = 0.0, 0.5, 1, 1.5, 2, 3, 5, 7 and 10.
- Aerosols well mixed between 0 and 2 km.
- Total number of simulations = 2165.
- Simulation time = 2 months on 30 cores
- Convolution with SEVIRI solar channels $\rightarrow$ narrowband radiances

Least Squares Fit

- We minimize a cost function $S(x)$ given by,

$$S(x) = r_i(x) W_{ij} r_j(x)$$

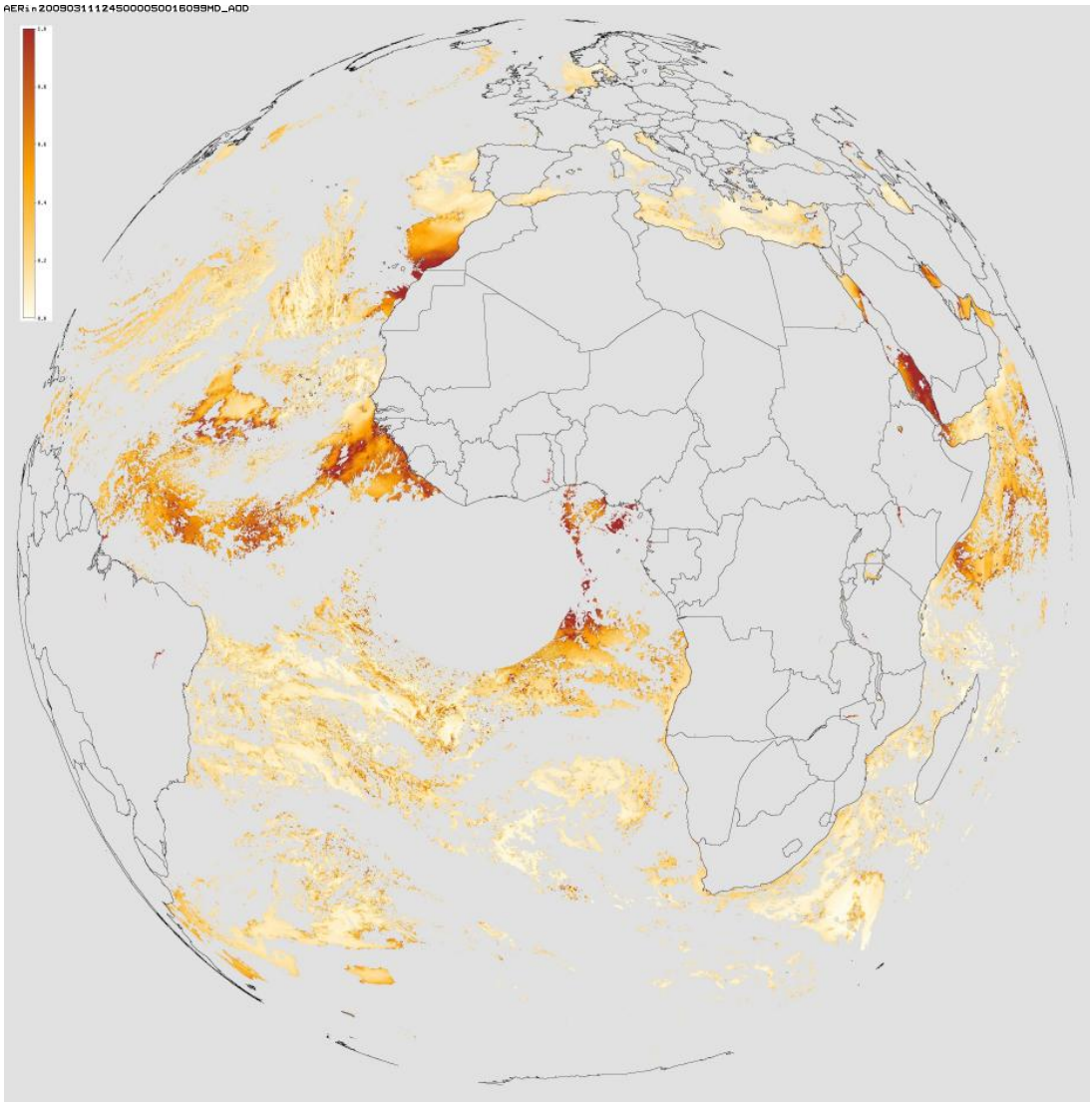
- Indices run over solar channels (635, 810, 1640) nm
- Weighting matrix $W = \mathrm{diag}\,[1, 1, 0]$
- $r_i(x)$ is the vector of residuals

$$r_i(x) = R_i - \tilde{R}_i(x)$$

- R_i = measured radiance
- $\tilde{R}_i(x)$ = simulated radiance given x
- $x \in \mathcal{R}^+ \times \mathcal{Z}_6$ (AOD $\times$ aerosol model)

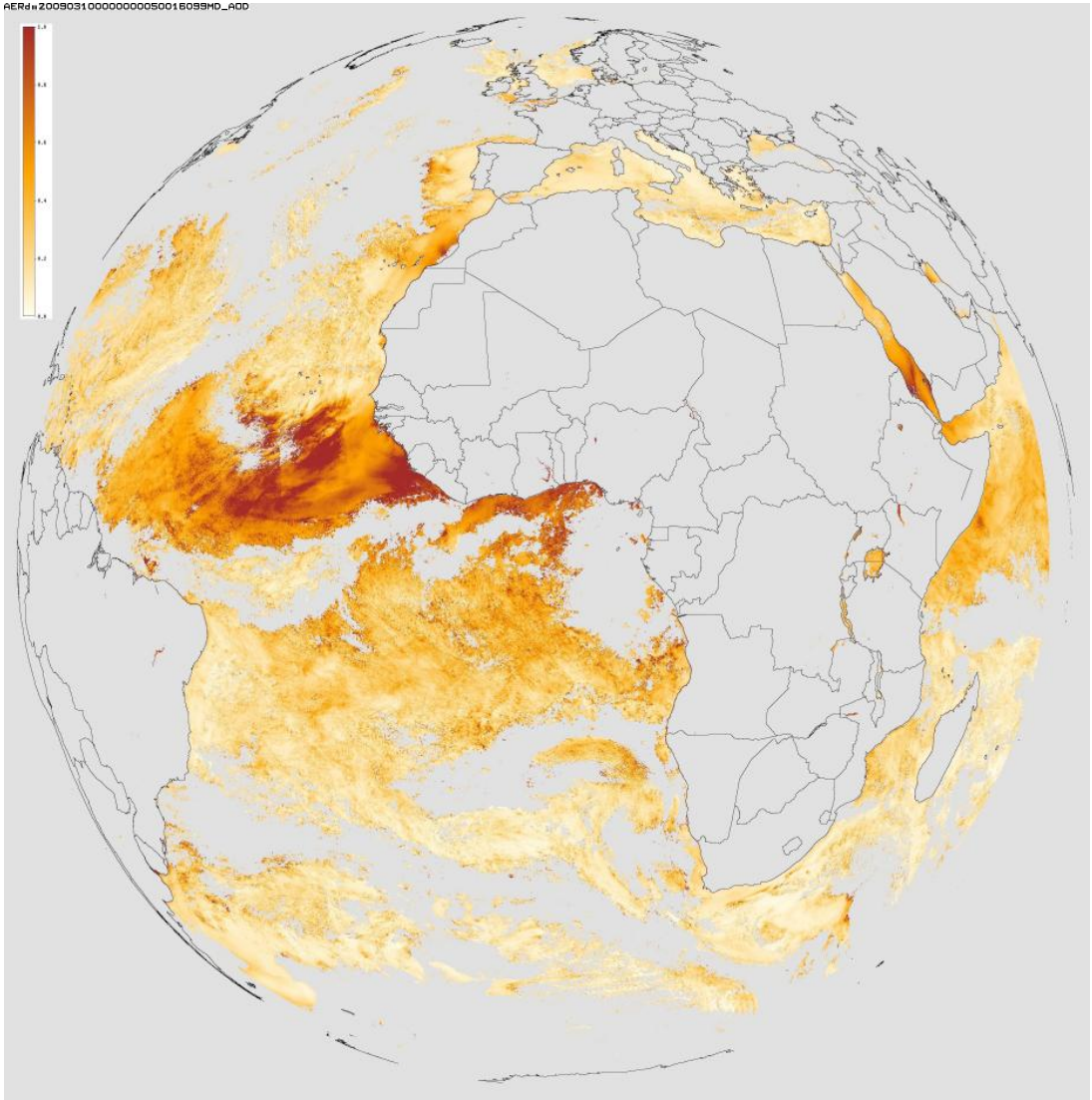
$\rightarrow$ Aerosol type and corresponding AOD that give the best agreement between observed and simulated reflectance.

Instantaneous AOD



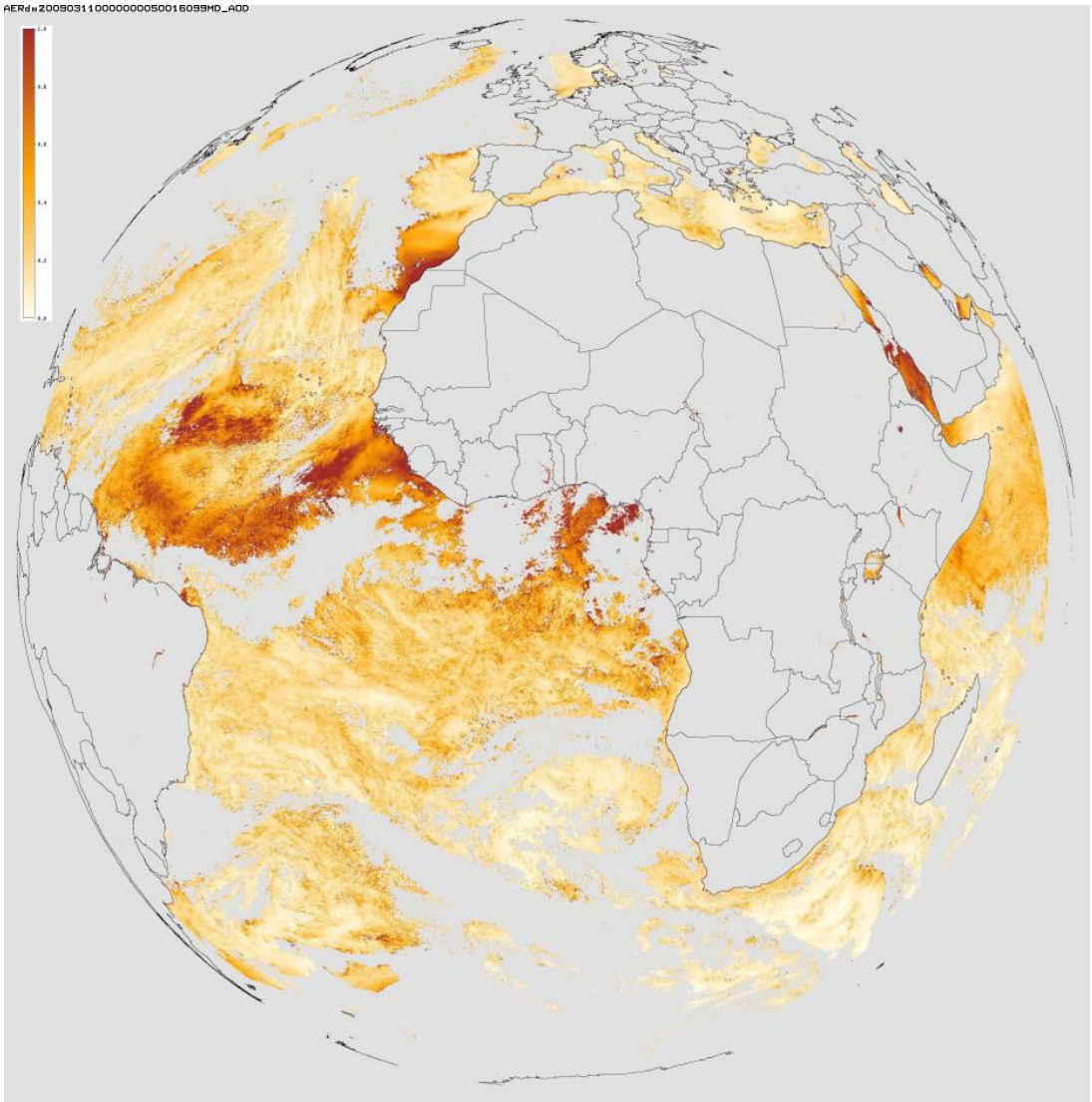
AOD on 2009/03/11 at 12:45, dust storm Saudi Arabia

Daily Mean AOD



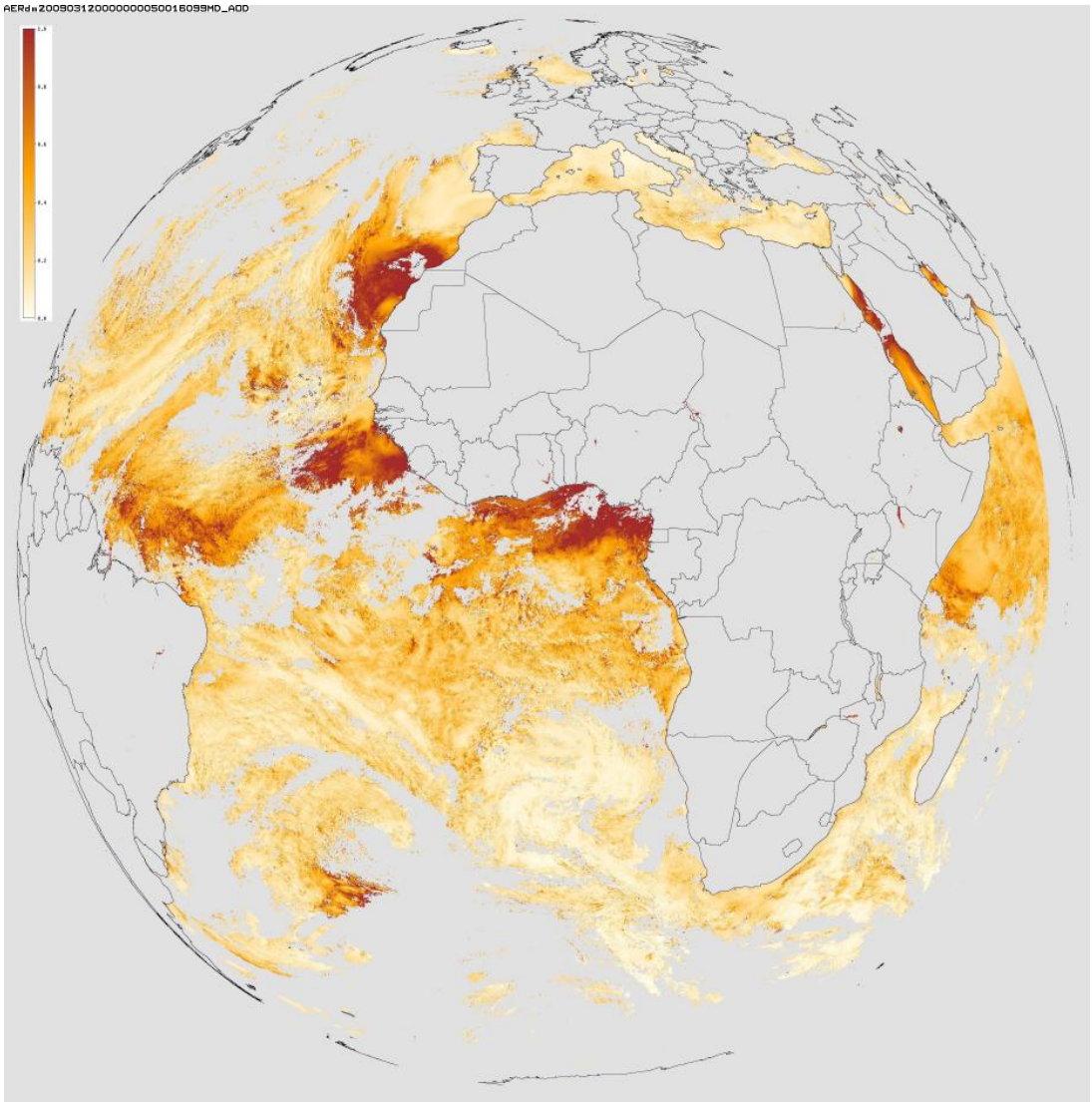
AOD 2009/03/10, dust storm Saudi Arabia 2009/03/11

Daily Mean AOD



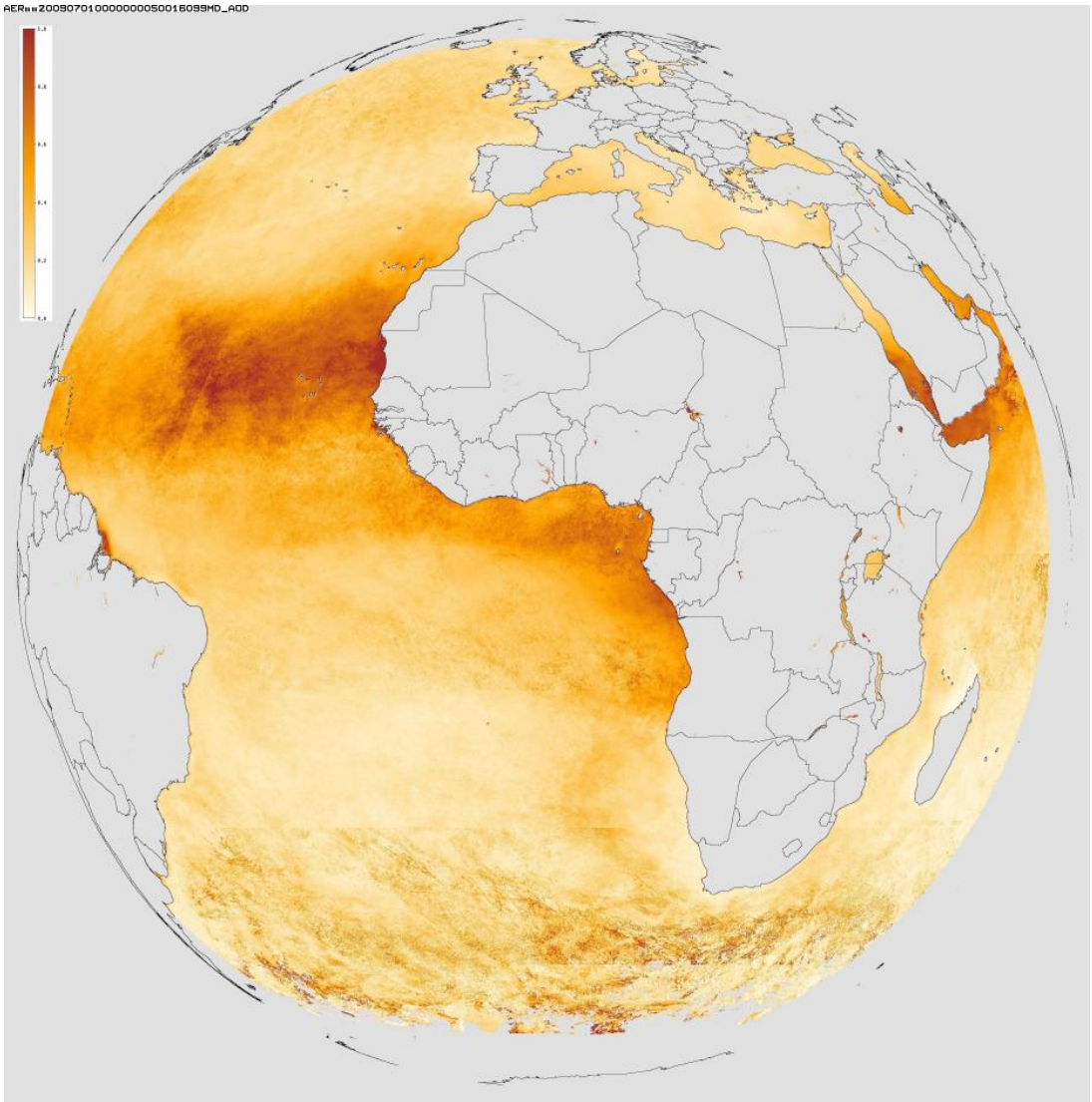
AOD 2009/03/11, dust storm Saudi Arabia 2009/03/11

Daily Mean AOD



AOD 2009/03/12, dust storm Saudi Arabia 2009/03/11

Monthly Mean AOD

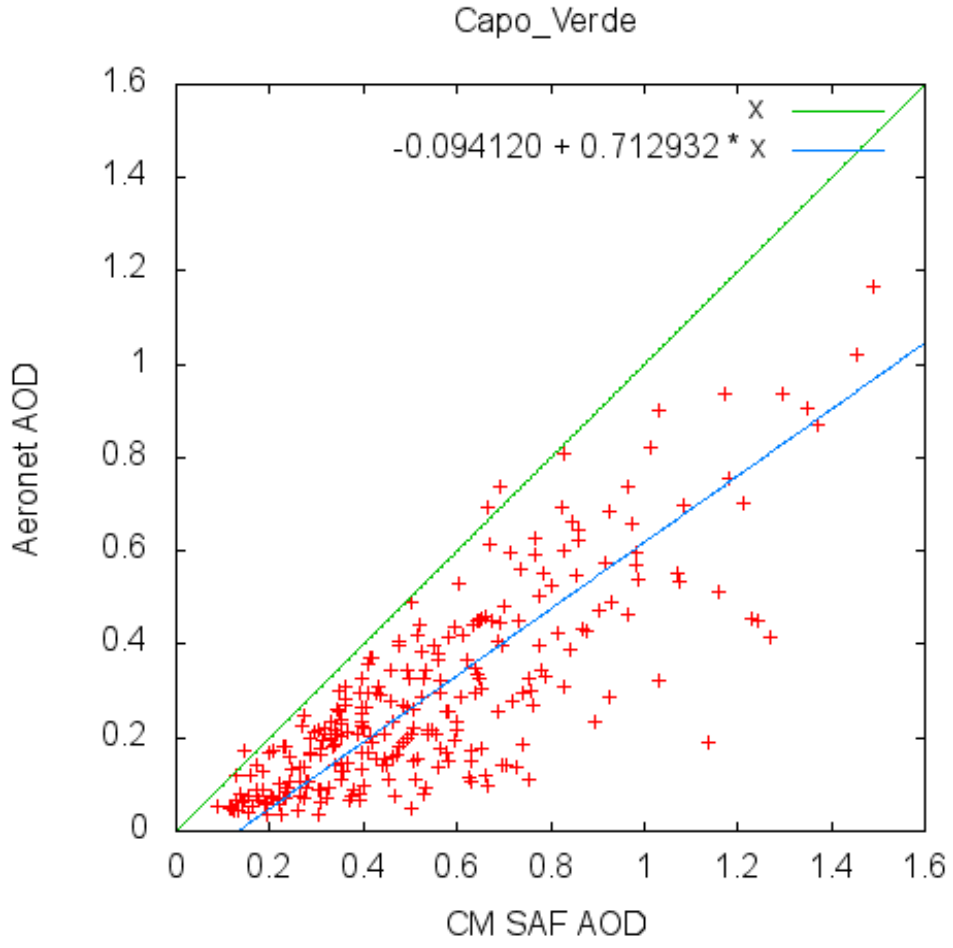


AOD 2009/07

Comparison With Aeronet

Comparison CM-SAF vs Aeronet Site over 2009, linear fit:

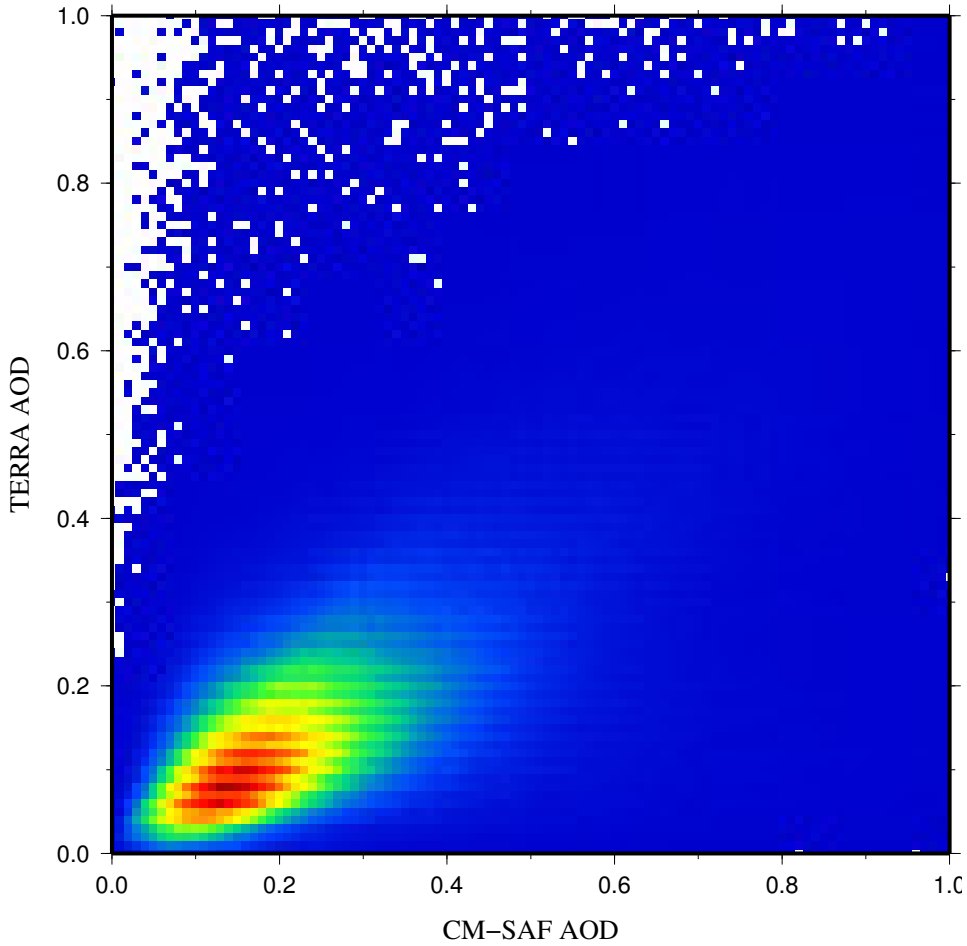
$$\text{AER} = -0.094120 + 0.712932 \times \text{CMSAF} \quad \rho = 0.811770$$



Comparison With TERRA Daily Mean

Comparison CM-SAF vs TERRA over 2009, linear fit:

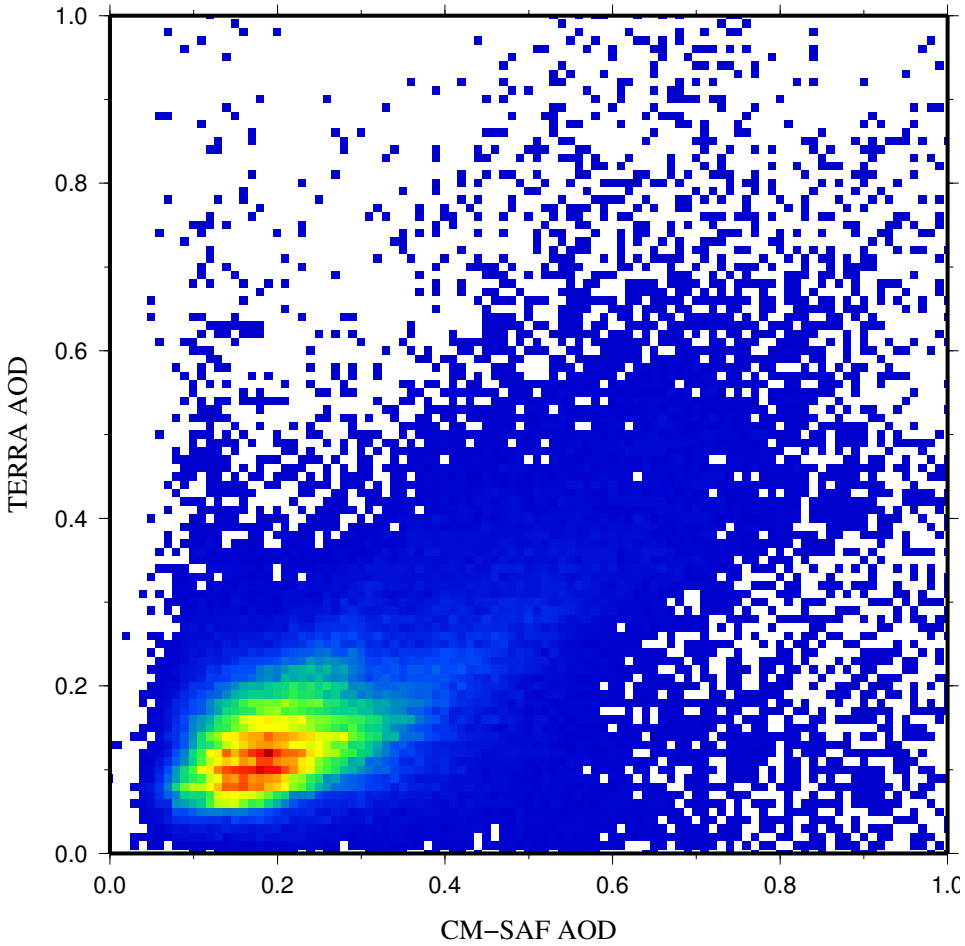
$$\text{TERRA} = -0.013219 + 0.703596 \times \text{CMSAF} \quad \rho = 0.624839$$



Comparison With TERRA Monthly Mean

Comparison CM-SAF vs TERRA over 2009, linear fit:

$$\text{TERRA} = -0.006694 + 0.665324 \times \text{CMSAF} \quad \rho = 0.609312$$



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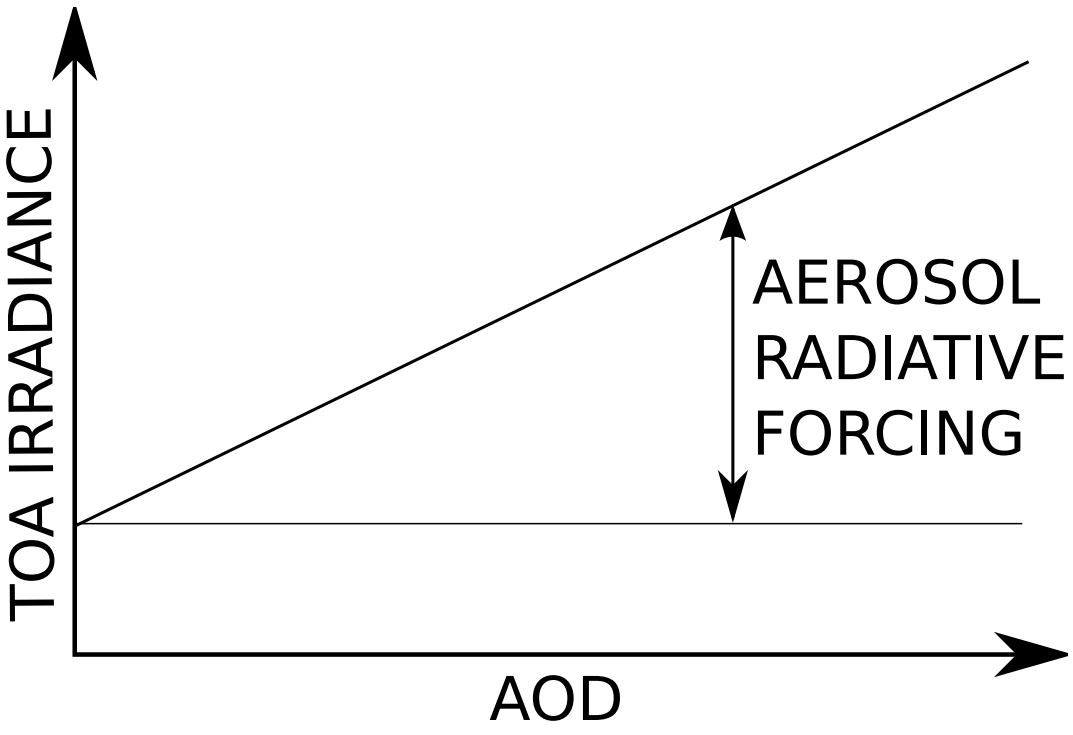
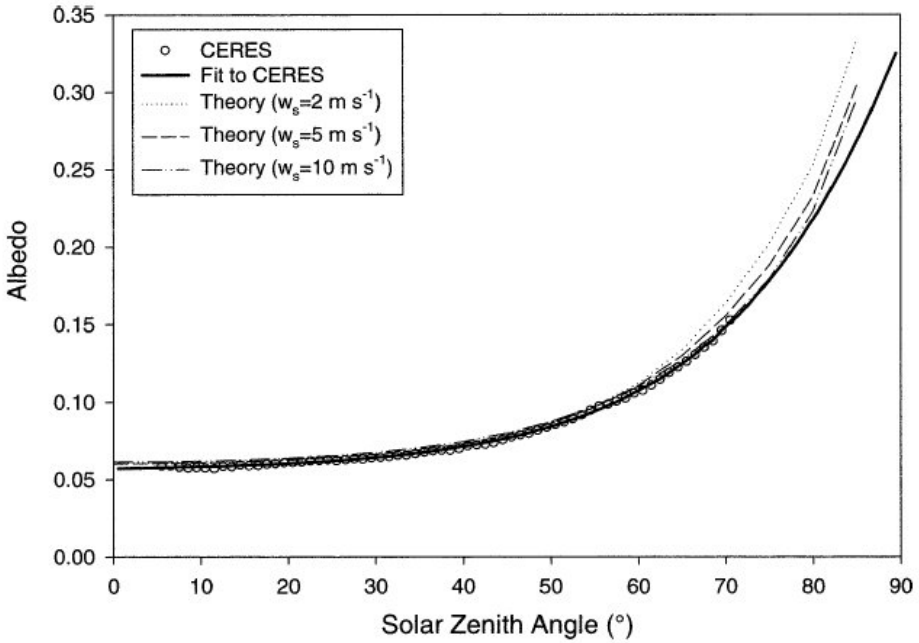
Methodology



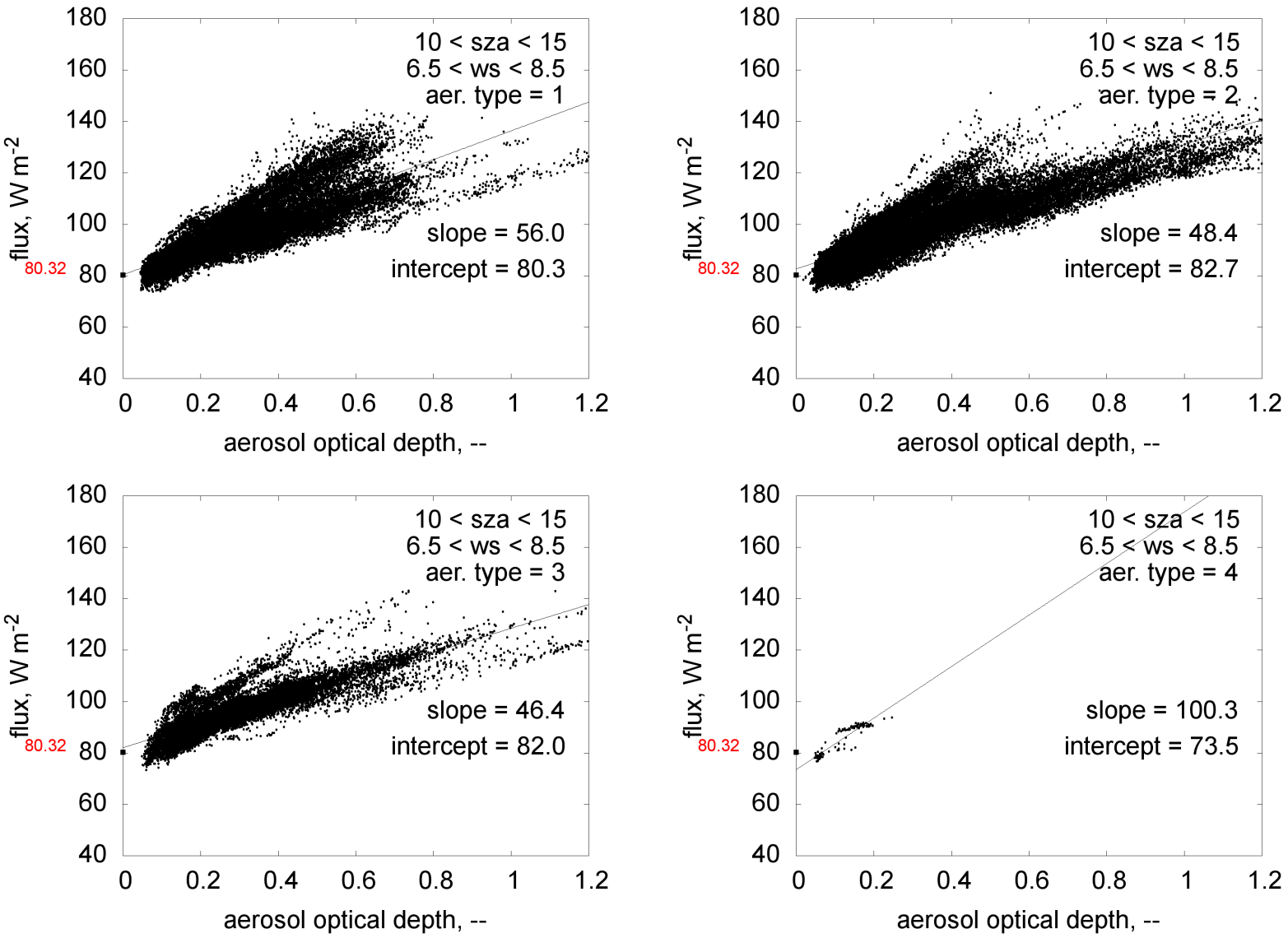
- Use the relation above to calculate slope and intercept (pristine flux) in a TOA irradiance (GERB or GERB like)
- Slope $\rightarrow$ radiative forcing corresponding to given AOD.

Regression of (AOD,flux)-data

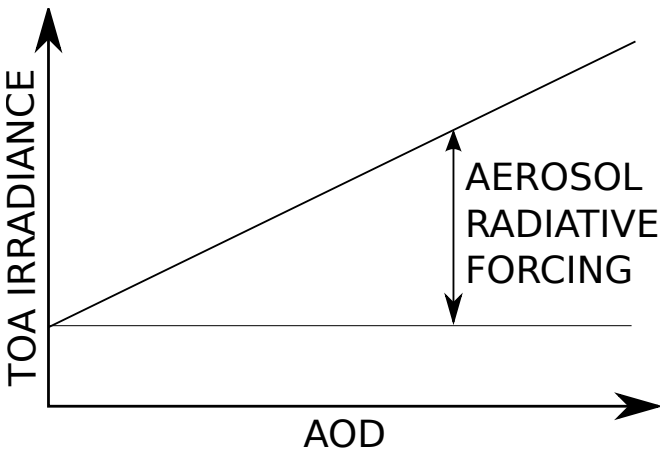


- Subdivided by aerosol type
  - Regression of a linear model on AOD vs. flux data
  - Binned by SZA, wind speed, aerosol type
  - Estimating slope
- All aerosol types together
  - Regression of a linear model on AOD vs. flux data
  - Binned by SZA, wind speed
  - Estimating intercept (pristine flux)

Regression of (AOD,flux)-data



Direct aerosol radiative forcing



Two different methods

1. Based on GERB (method #1)

$$-F_{\mathrm{DAF}} = F_{\mathrm{SW}} - F_{\mathrm{pristine}}$$

(Variation on method #1 with CM-SAF cloud mask, validation only: method #1-C)

2. Based on SEVIRI (method #2)

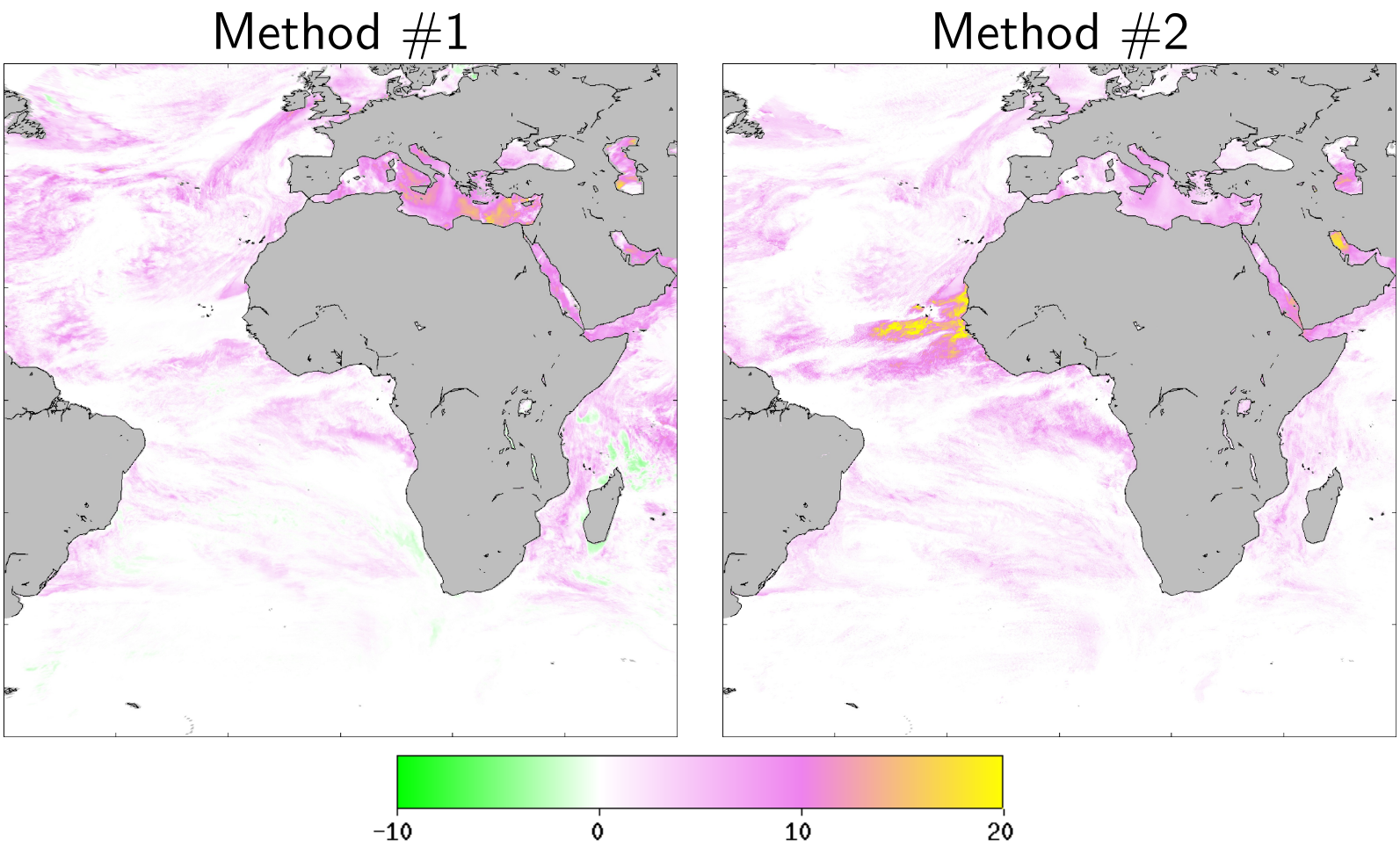
$$-F_{\mathrm{DAF}} = \mathrm{slope} \times \mathrm{AOD}$$

Comparison of methods

	Method #1	Method #2
Based on	Intercept	Slope
Needs instantaneous GERB	Yes	Not directly
Sensitive to GERB drift	Yes	No
Sensitive to GERB SW ADM	Yes	No
Sensitive to AOD drift	No	Yes
Spatial resolution	GERB HR $(9\ \mathrm{km})^2$	SEVIRI $(3\ \mathrm{km})^2$
Sensitive to aerosol type	None	Linear
Cloud mask	Underestimated	Overestimated
Temporal resolution	15 minutes	1 hour

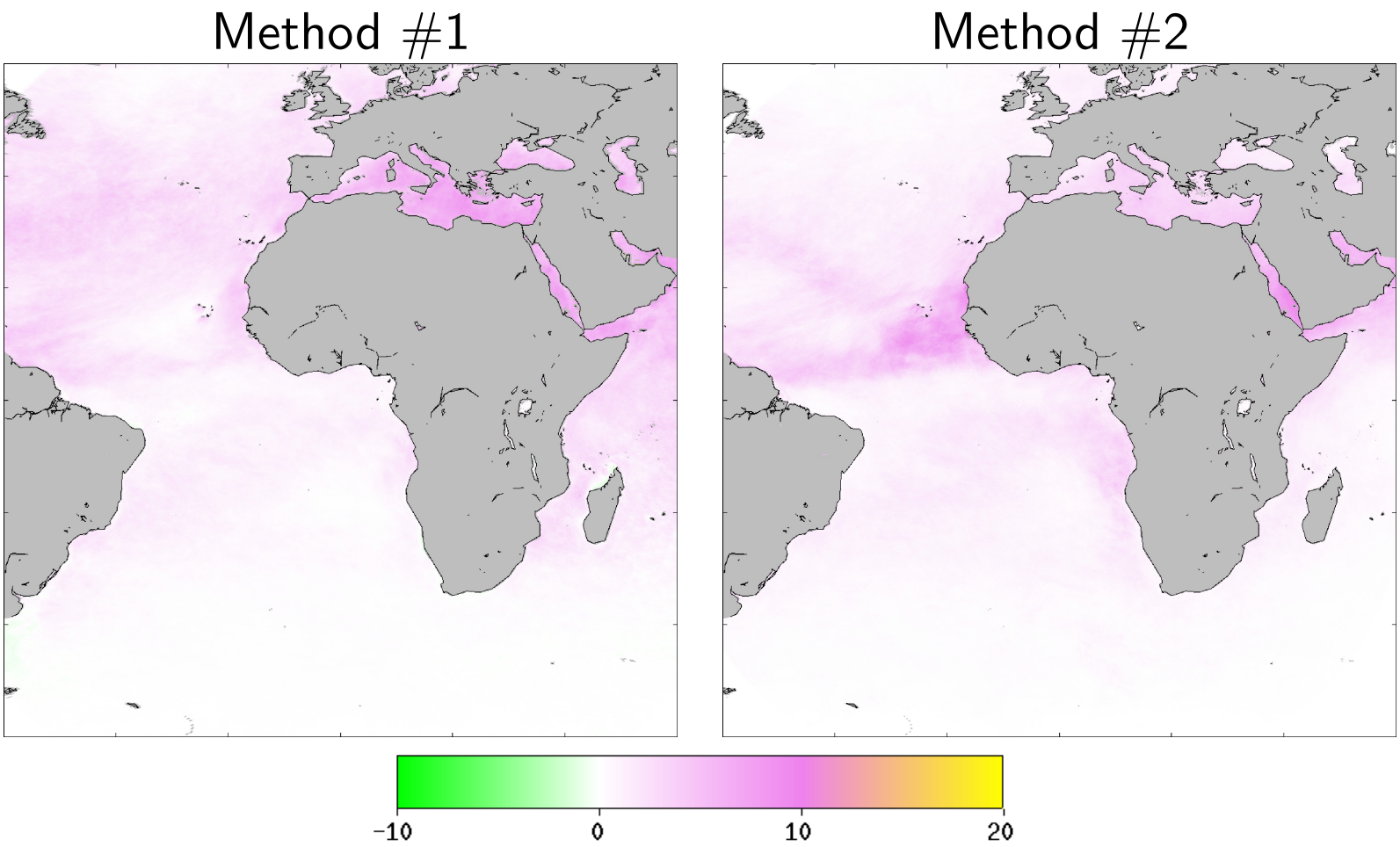
Direct aerosol radiative forcing: daily mean

24 May 2009, Forcing (Sign reversed), W m^{-2}



Direct aerosol radiative forcing: monthly mean

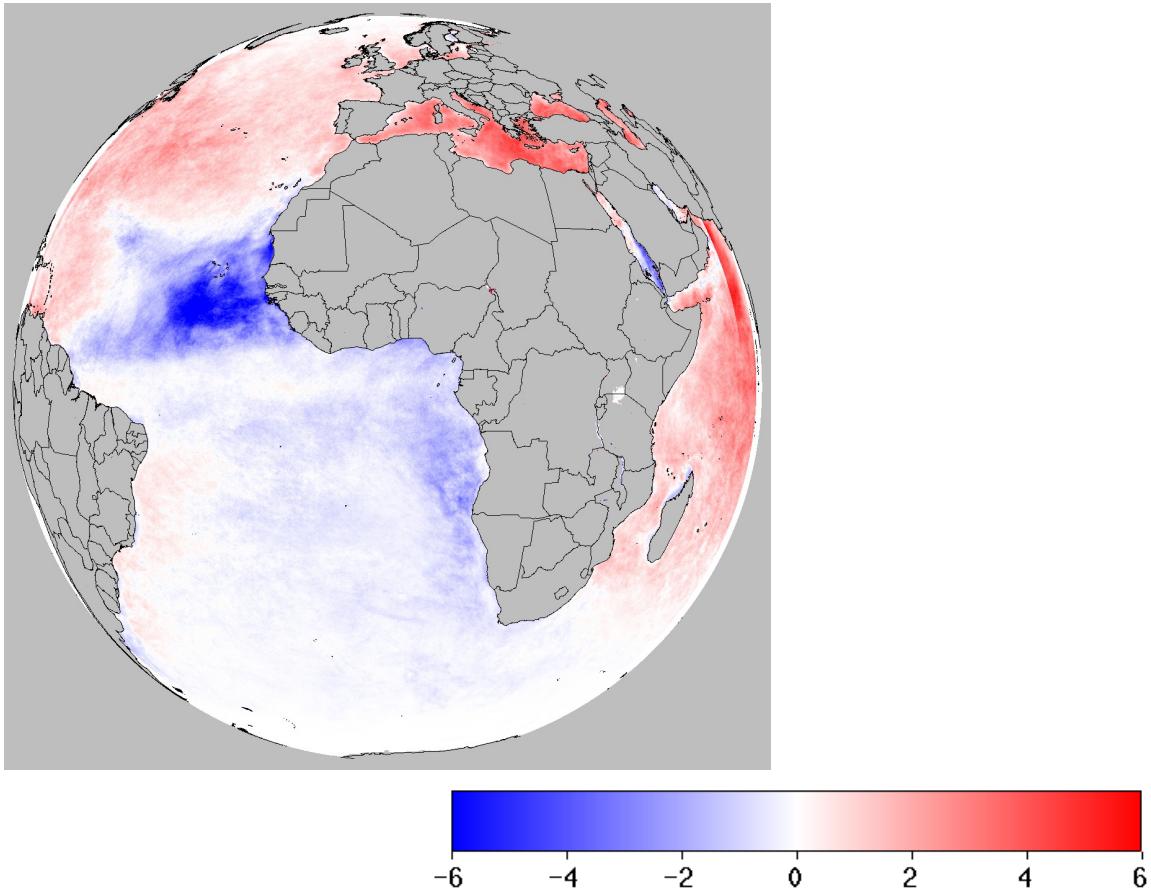
May 2009, Forcing (Sign reversed), W m^{-2}



Comparison of methods

May 2009, Difference, W m^{-2}

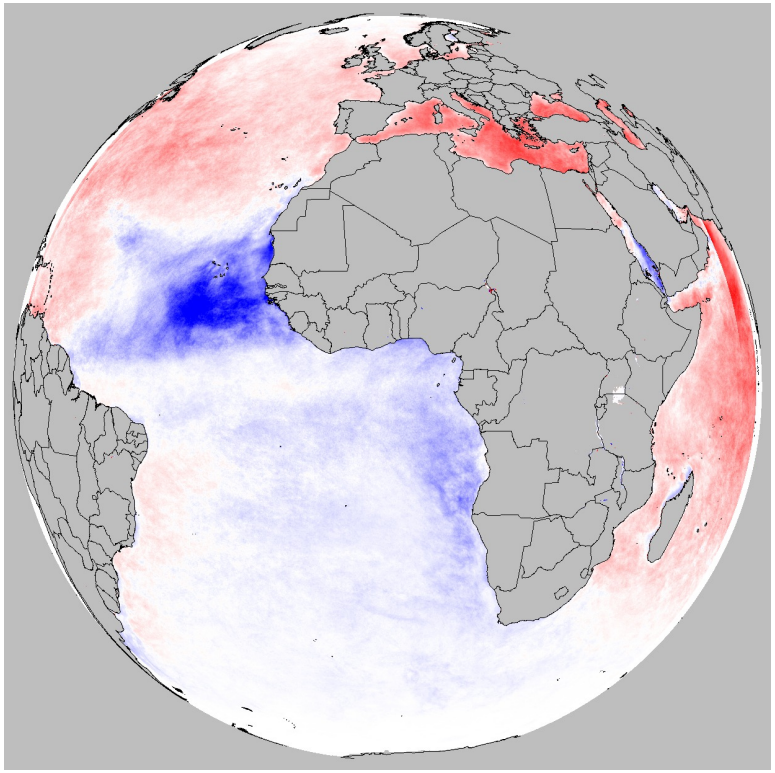
Method #1 − Method #2



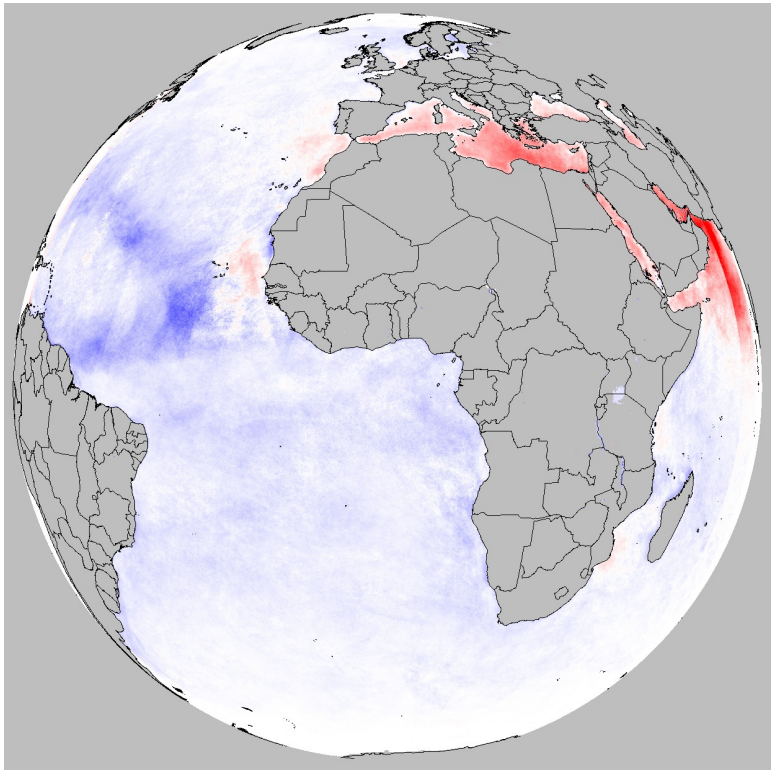
Comparison of methods

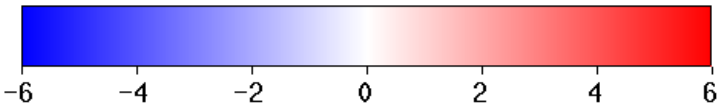
May 2009, Difference, W m^{-2}

Method #1 – Method #2



Method #1-C – Method #2

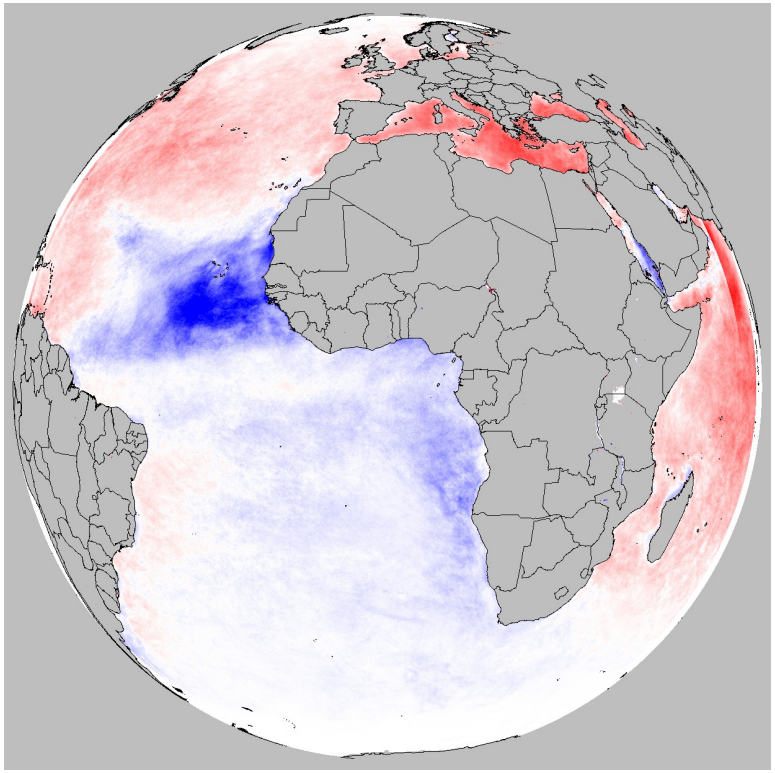
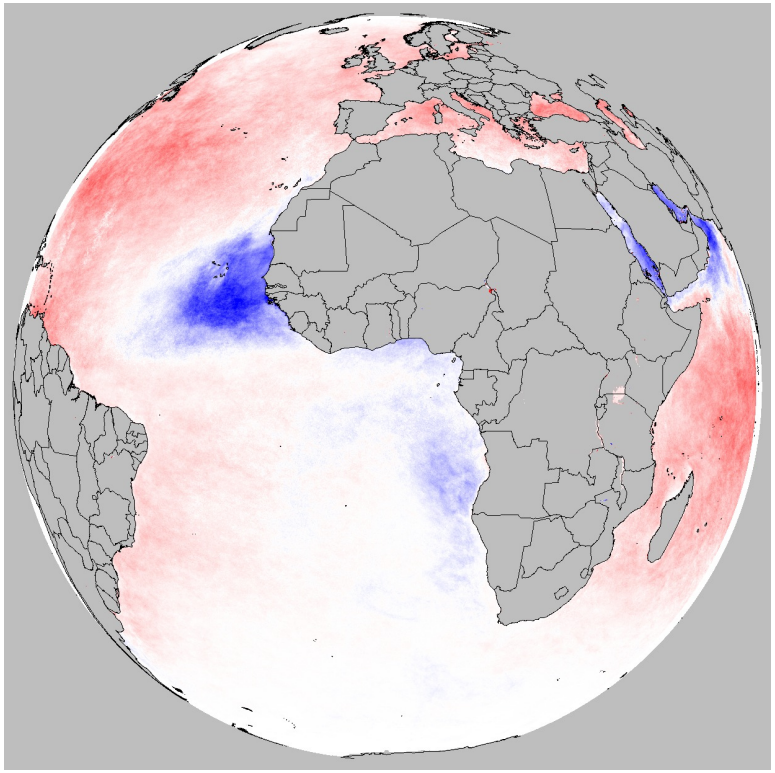
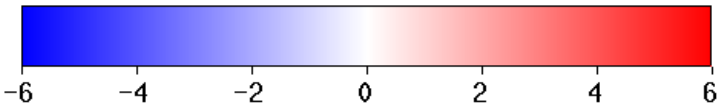




Comparison of methods

May 2009, Difference, W m^{-2}

Method #1 – Method #2



Method #1 – Method #1-C