Edition 4 clear-sky shortwave Angular Distribution Models over ocean

Lusheng Liang[1], Wenying Su[2], Joseph Corbett[1] and Zachary Eitzen[1]

1 – SSAI; 2 – NASA, LaRC

radiance to flux: clear-sky SW ADMs over ocean

1. Sort measured radiances into angular and wind speed bins (w; θ_0, θ, ϕ) and calculate mean radiances;

2. Calculate mean flux by integrating the mean radiances over all θ and ϕ;

3. Define anisotropic factor;

4. Convert measured radiances to fluxes.

$$\hat{I}(w;\theta_0,\theta,\varphi)$$

$$\hat{F}(w;\theta_0)$$

$$R(w;\theta_0,\theta,\varphi) = \frac{\pi\hat{I}(w;\theta_0,\theta,\varphi)}{\hat{F}(w;\theta_0)}$$

$$F = \frac{\pi I_o(w;\theta_0,\theta,\varphi)}{R(w;\theta_0,\theta,\varphi)}$$

Aerosol in Ed.2 Clear-sky ADMs over Ocean

- Aerosol is not directly accounted for in Ed.2 ADM;
- It is implicitly accounted for by a theoretical scale factor when radiances are converted to fluxes (*Loeb et al., 2005*).

$$F = \frac{\pi I_O}{R\left(\frac{R^{th}_{I_O}}{R^{th}_{\hat{I}}}\right)}$$

- R is the anisotropic factor for converting $\hat{I}$ at (w, θ_0, θ and ϕ) to F;
- $R^{th}_{\hat{I}}$ is the theoretical anisotropic factor for $\hat{I}$;
- $R^{th}_{I_0}$ is the theoretical anisotropic factor for I_0 .

How to quantify the performance of an ADM?

RMS of normalized radiance differences between ADM-prediction and observation

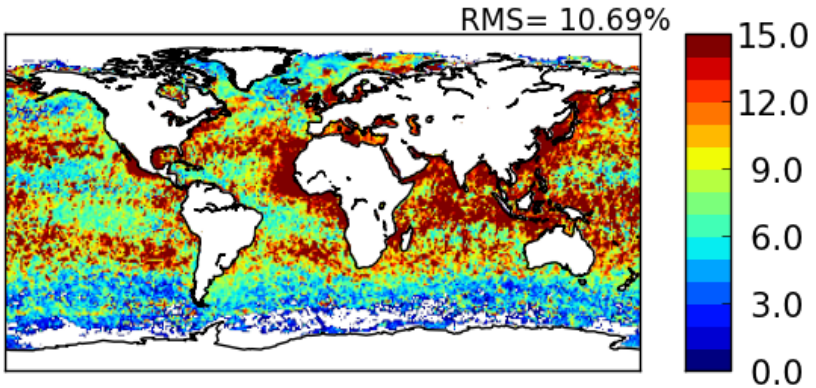
$$RMS = \sqrt{\frac{1}{n}\sum\left(\frac{\hat{I}^i}{\langle \hat{I} \rangle} - \frac{I_O^i}{\langle I_O \rangle}\right)^2}$$

$\hat{I}^i$ is the radiance value of ADM at (w, θ_0, θ and ϕ),

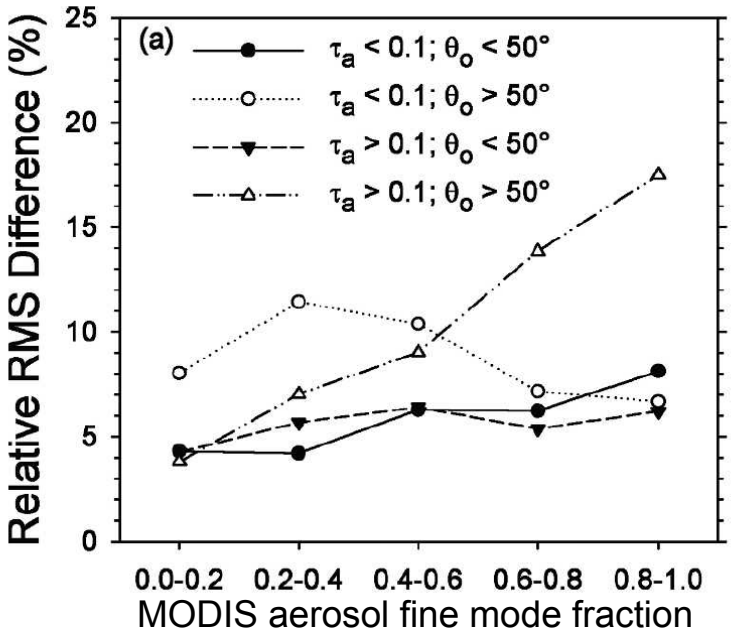
I_o^i is the radiance value of the theoretical model at (w, θ_0, θ and ϕ),

$\langle\ \rangle$ is the grid mean.

Where to improve?



RMS is a function of AOD and aerosol type



Flux viewing angular consistency depends on aerosol fine mode fraction (Loeb et al., 2007)

Aerosol retrievals

Two options to obtain aerosol information

- Use MODIS aerosol product
- Develop our own version of aerosol retrievals

Why do we prefer to developing our own version of aerosol retrievals?

- MODIS aerosol retrieval is not produced purposely for CERES flux inversion. Not every clear-sky FOV over ocean has a MODIS aerosol retrieval, ~8.3% of clear CERES FOVs do not have MODIS aerosol retrievals.
- Our own aerosol retrieval is self-consistent with CERES-MODIS cloud mask.
- MODIS aerosol retrieval is only available for glint angle > 40°.

Aerosol retrievals

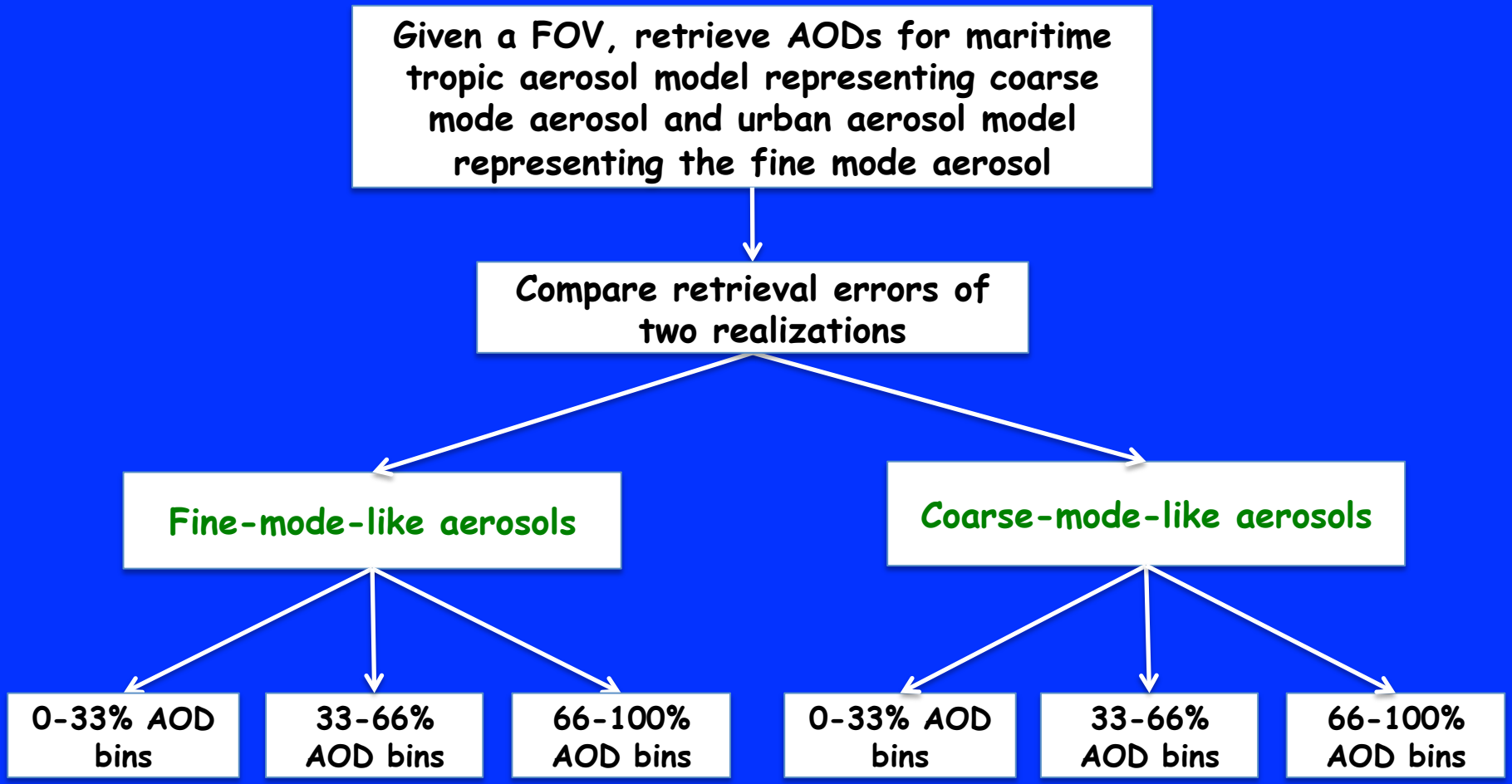
- Five MODIS bands

  0.47um, 0.55um, 0.66um, 0.87um, 1.24um (Terra) and 2.13um(Aqua)

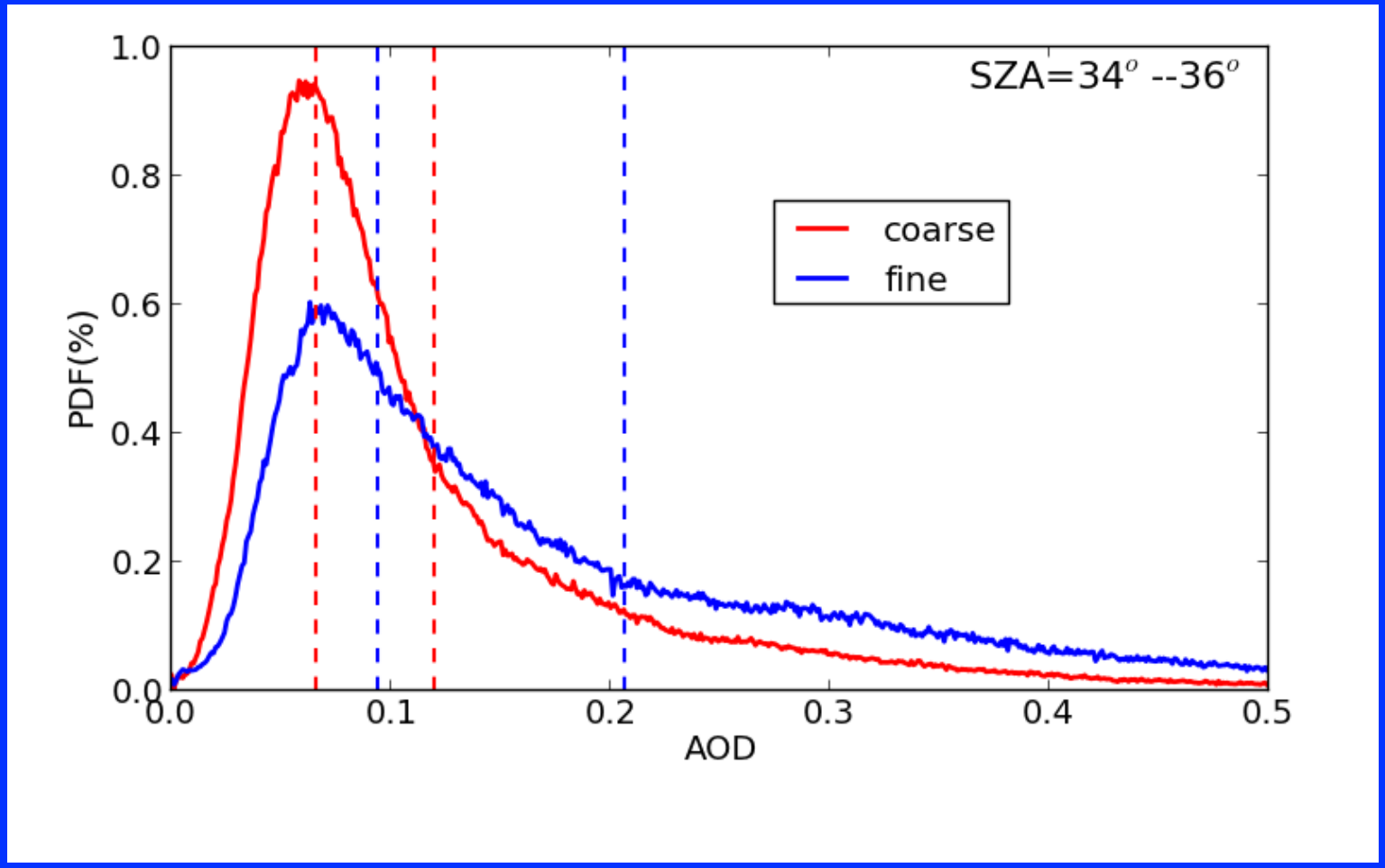
- For MODIS glint angle > 40°, two AOD values retrieved for two aerosol models: OPAC maritime tropic and urban models (Hess et al., 1998)

- For MODIS glint angle ≤ 40°, AOD is retrieved for OPAC maritime tropic aerosol model only

AOD-and-type classified ADMs for glint >40°

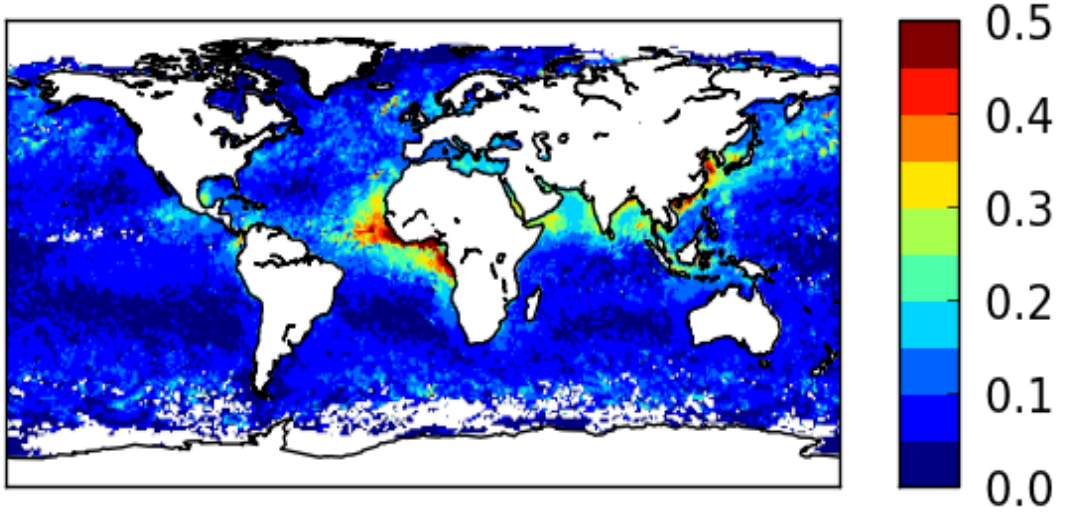


Percentile approach to sort FOVs

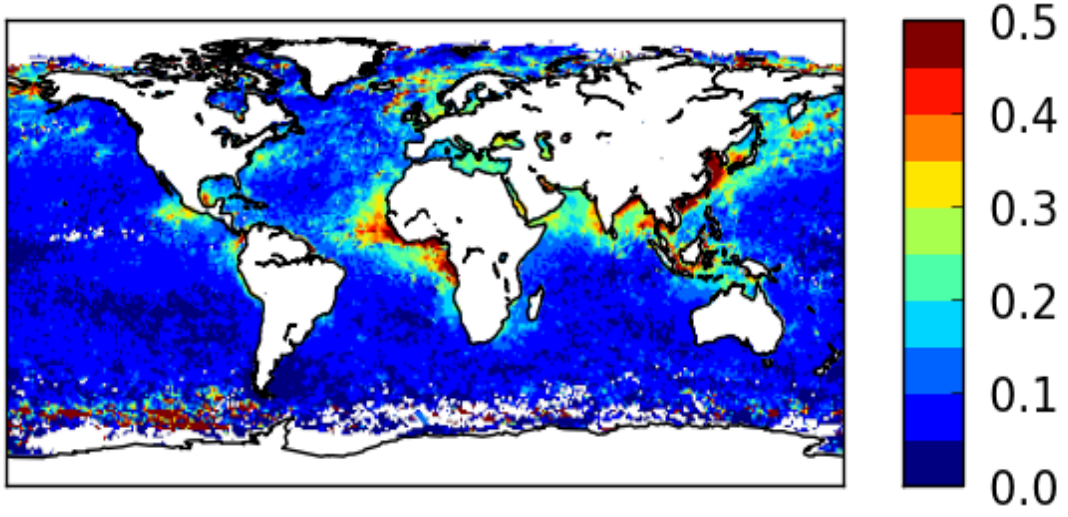


AOD retrieval – comparison with MODIS: glint angle > 40°

MODIS
Mean AOD=0.09

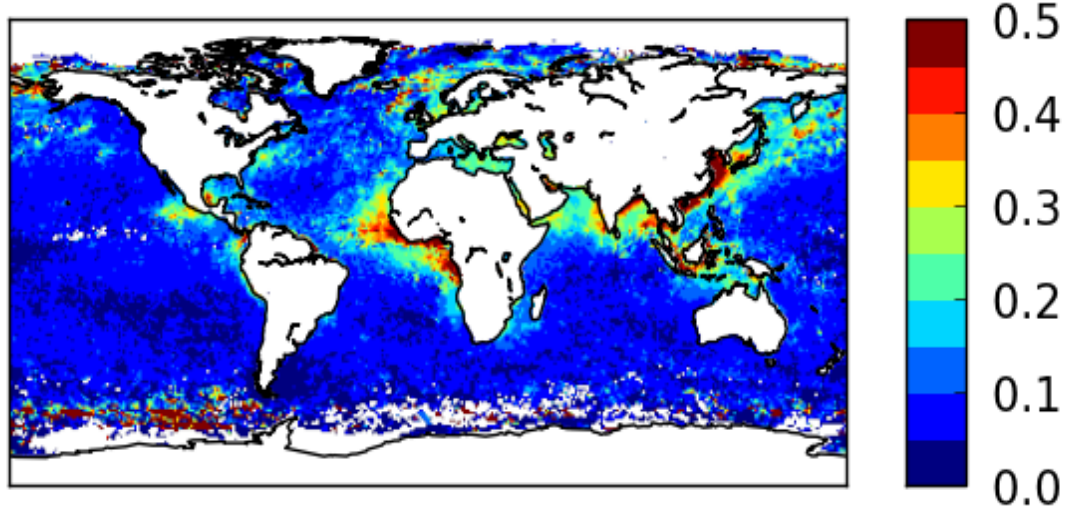


CERES
Mean AOD=0.13

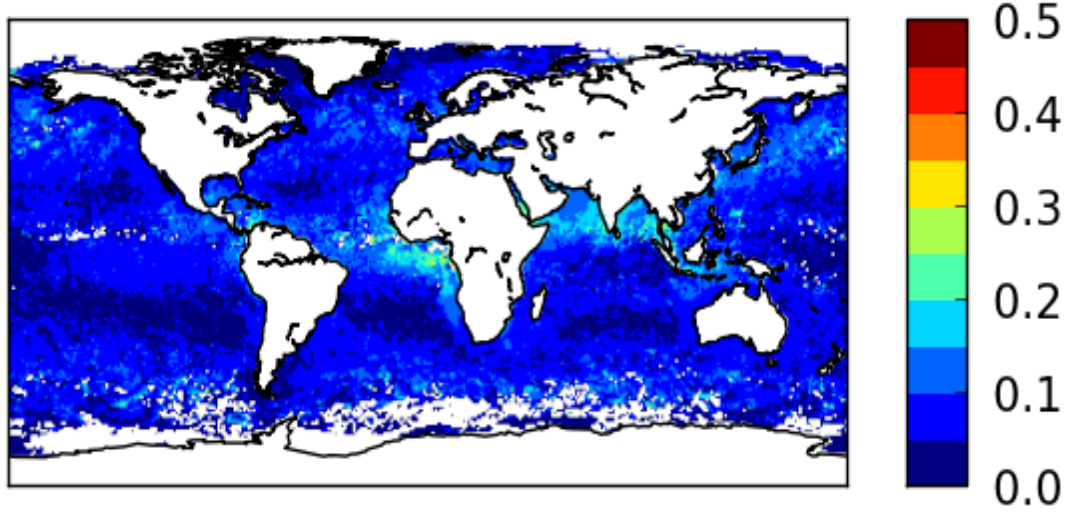


AOD retrieval – comparison with MODIS: glint angle > 40°

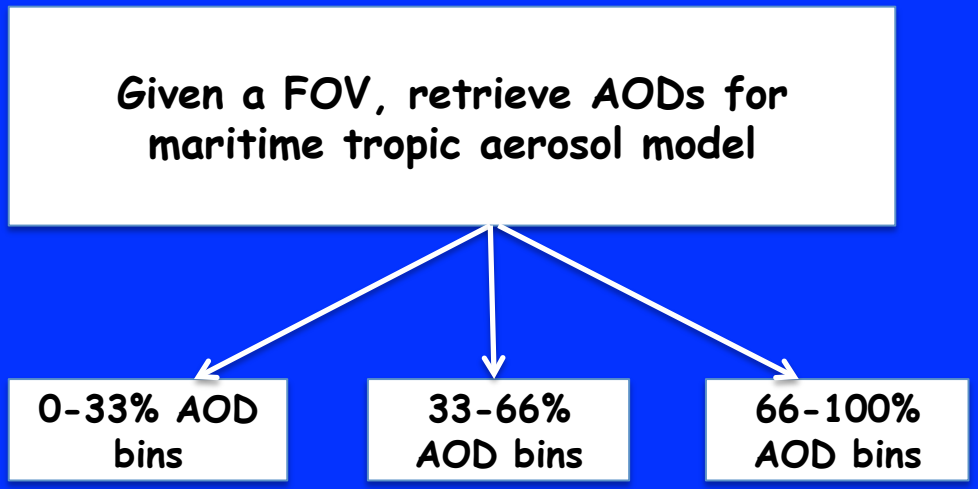
CERES
Mean AOD=0.13



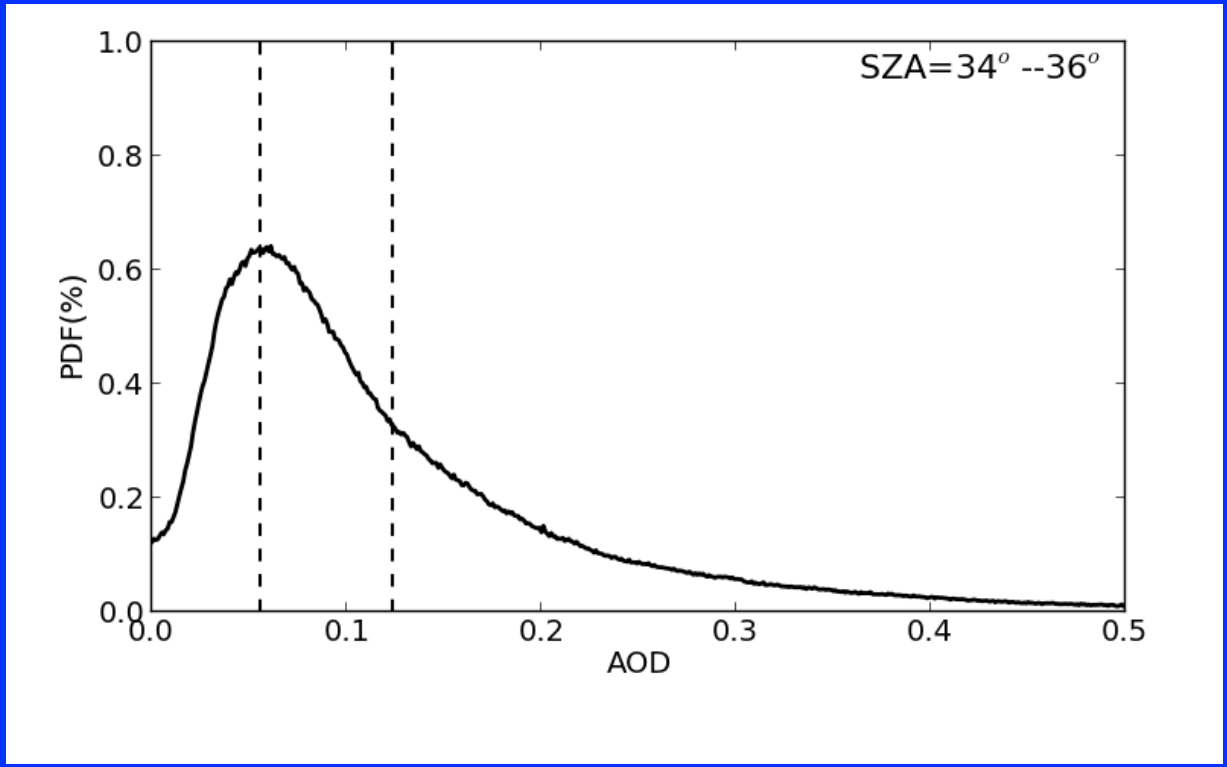
CERES
Mean AOD=0.07
(most clear conservative FOVs)



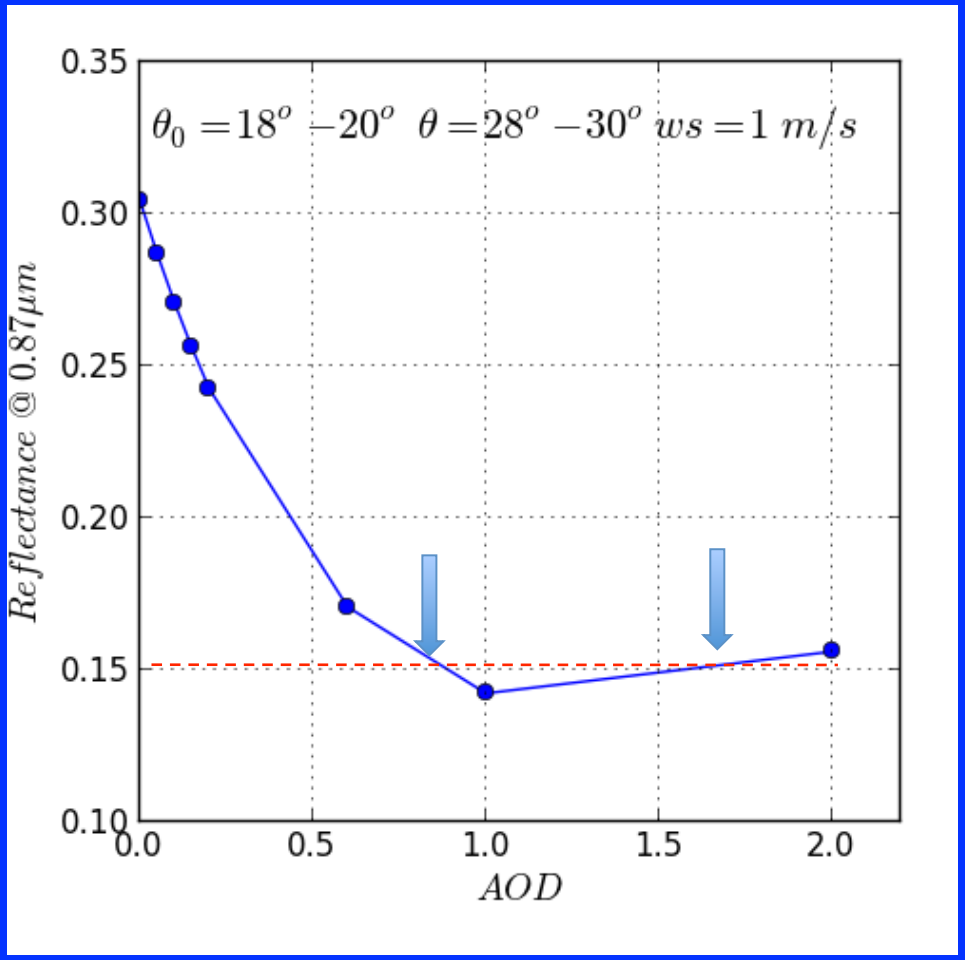
AOD classified ADMs for glint ≤ 40°



Percentile approach to sort FOVs

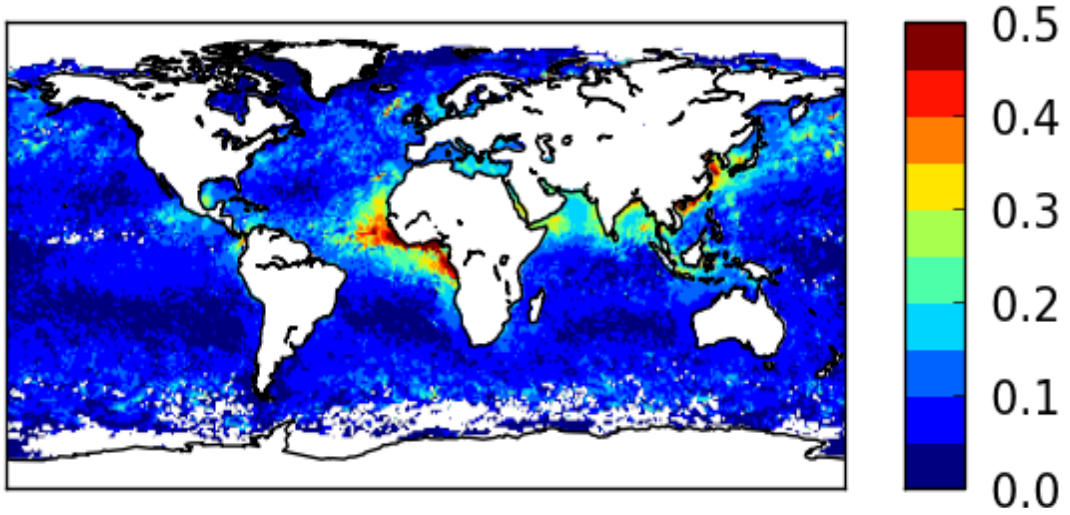


Ambiguity of AOD retrieval for glint ≤40°

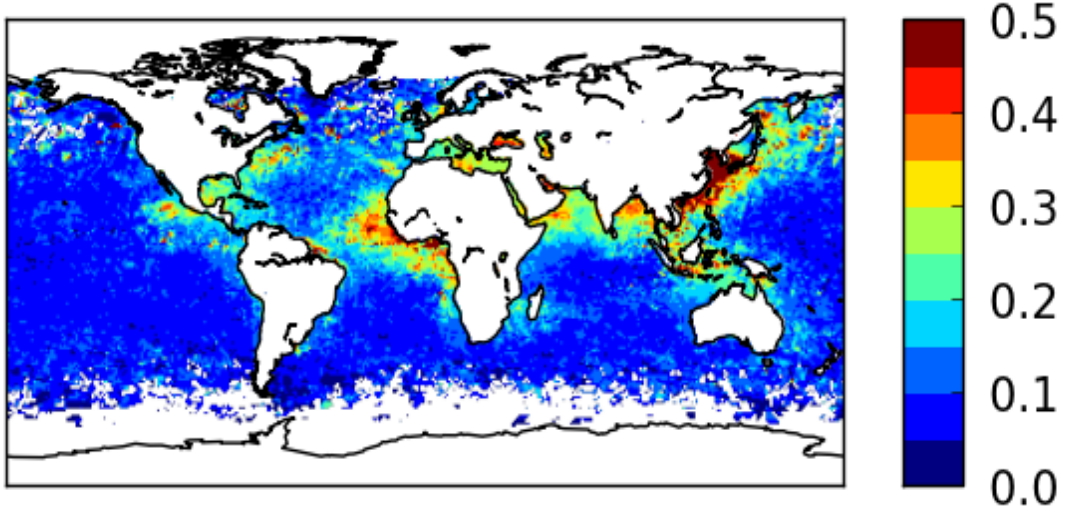


AOD retrieval – comparison with MODIS: glint angle ≤ 40°

MODIS
Mean AOD=0.09
(glint angle > 40°)



CERES
Mean AOD=0.13
(glint angle ≤ 40°)



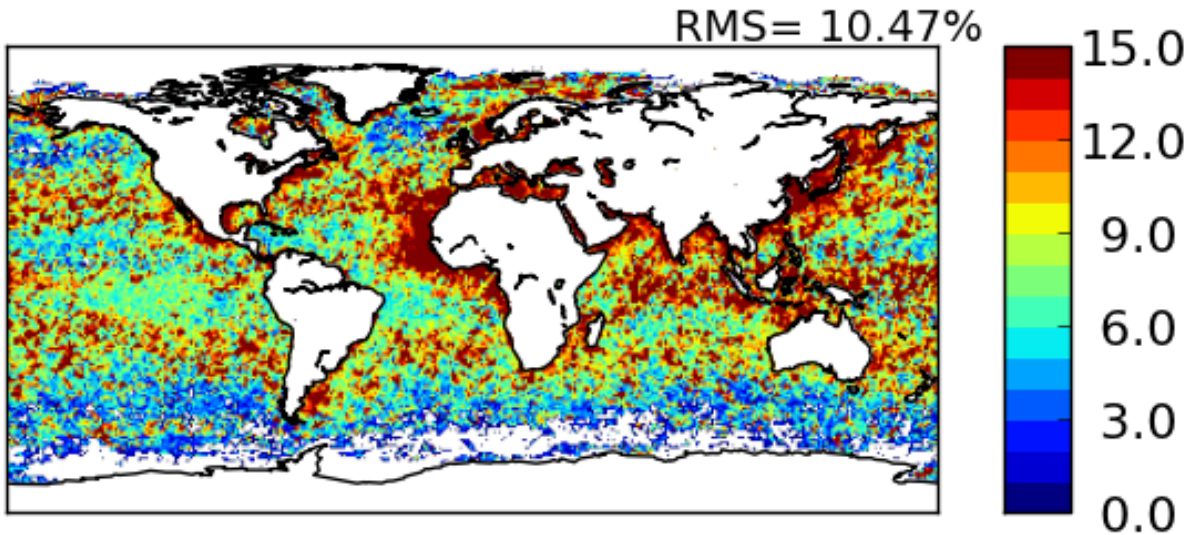
FOV sampling

<table>
<tr><td rowspan="3">Clear-sky FOVs over ocean
100%</td><td>FOVs with imager glint >40°
52% (one AOD realization)</td><td></td></tr>
<tr><td rowspan="2">FOVs with imager glint ≤ 40°
48%</td><td>Two AOD realizations
9%</td></tr>
<tr><td>One AOD realization
39%</td></tr>
</table>

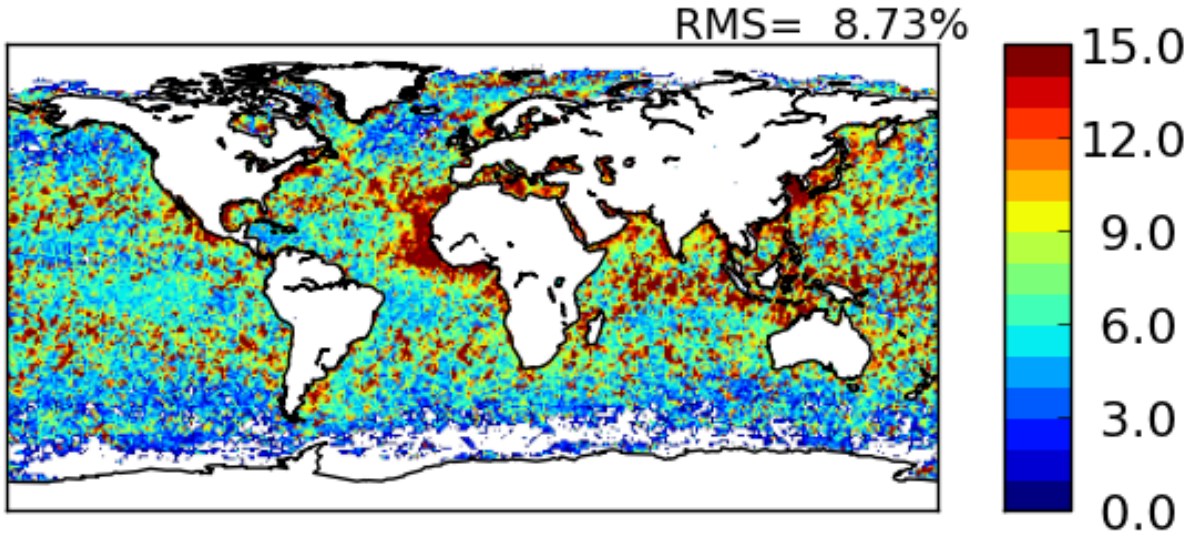
For a FOV with an AOD retrieval, flux is inverted by Ed4ADM.
Otherwise, the flux is inverted by the updated-Ed2ADM based on Ed4 SSFs.

ADM performance: Terra

update-Ed2ADM

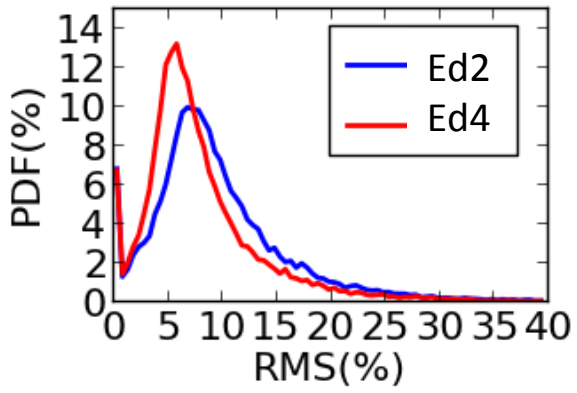


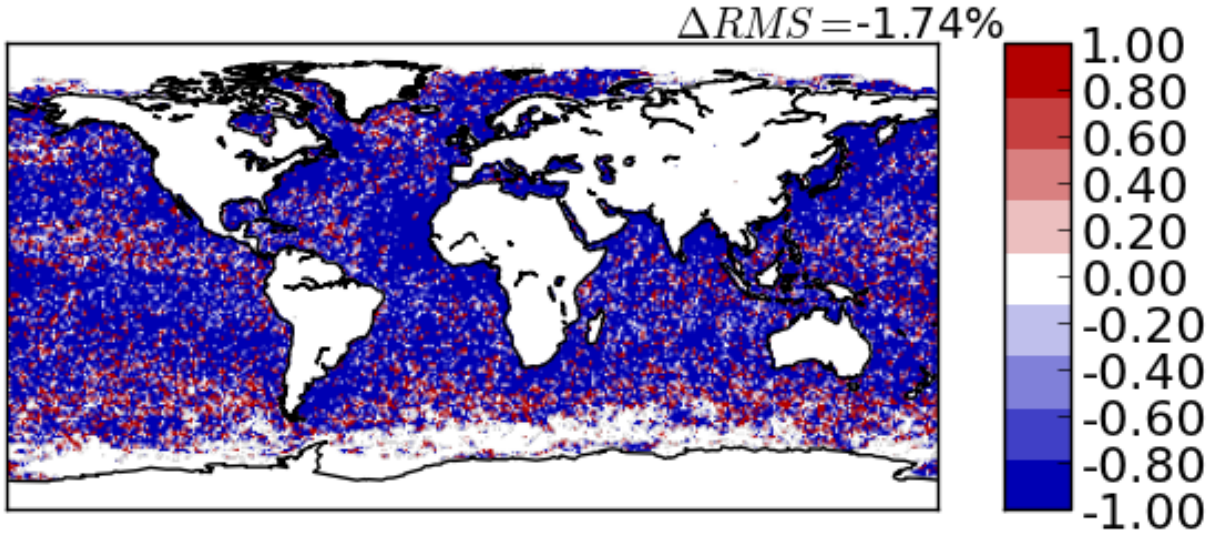
Ed4ADM

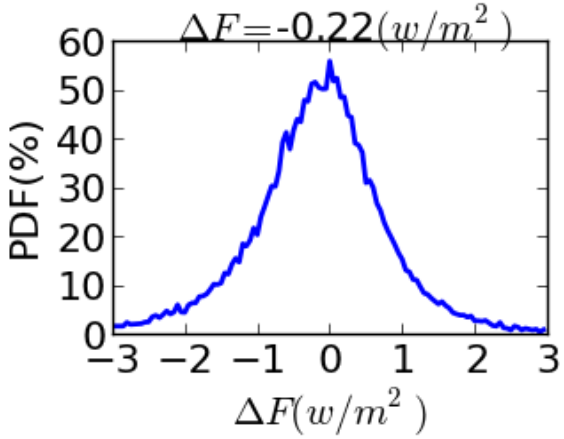


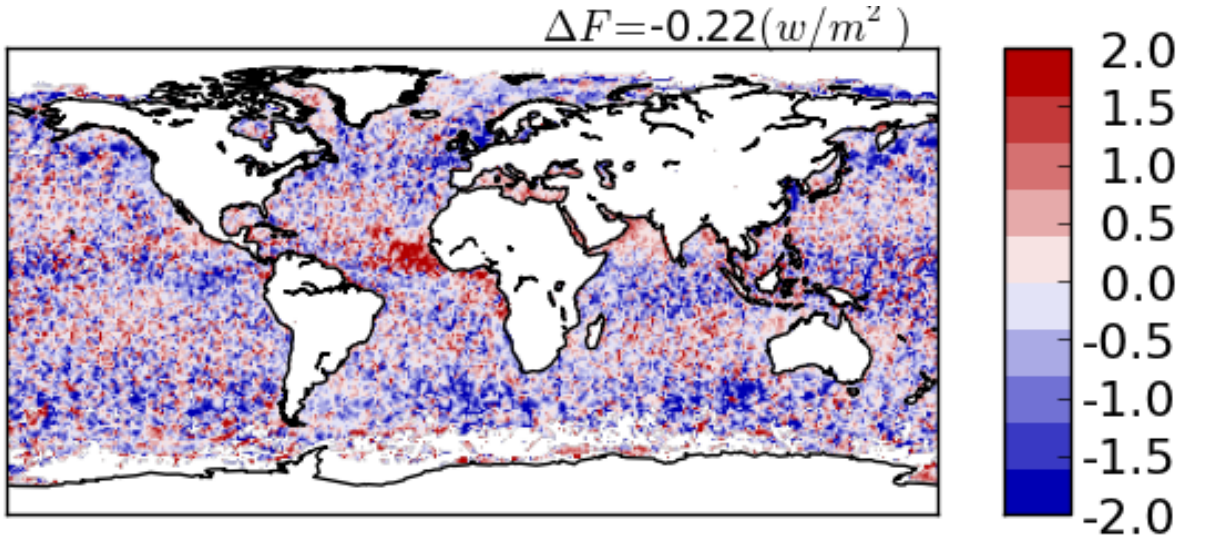
(2002, Terra rap mode)

ADM performance: Terra





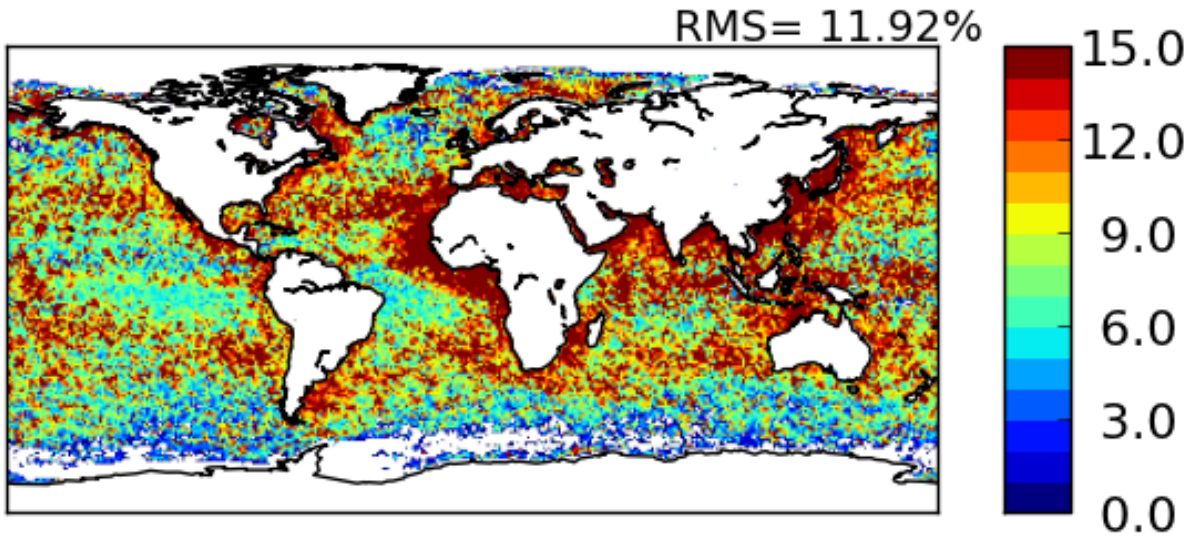




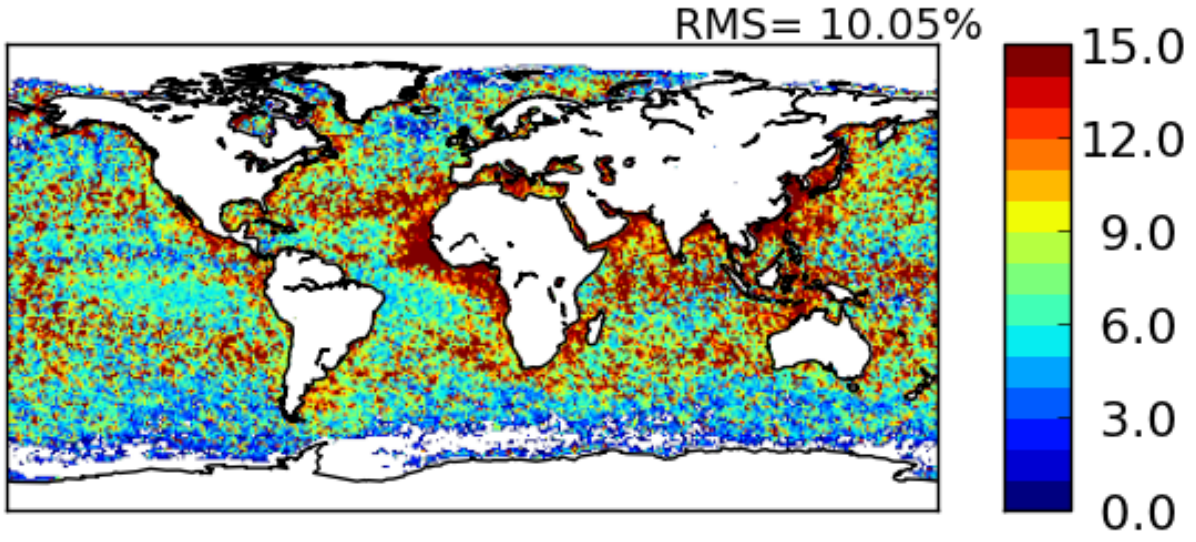
(2002, Terra rap mode)

ADM performance: Aqua

update-Ed2ADM

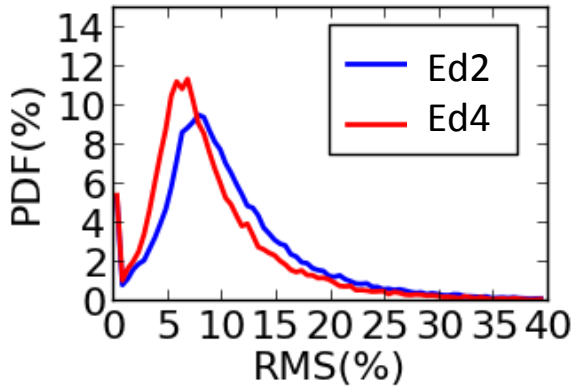


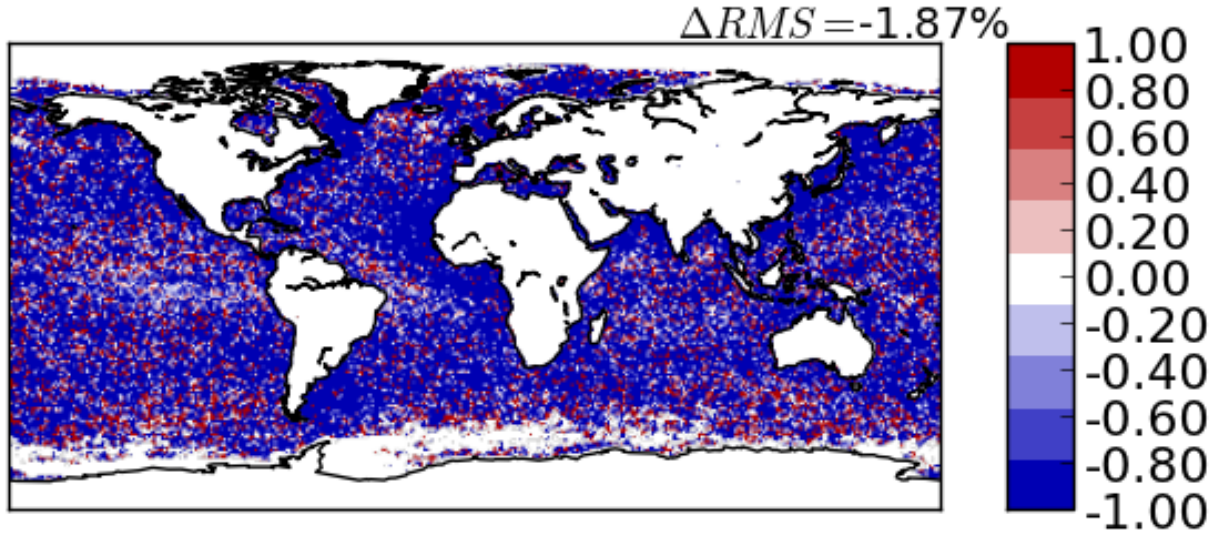
Ed4ADM

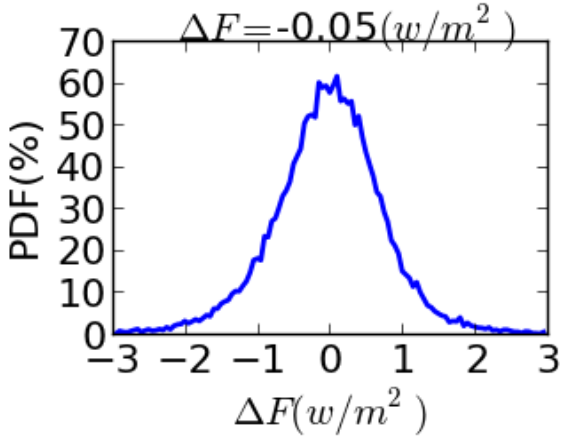


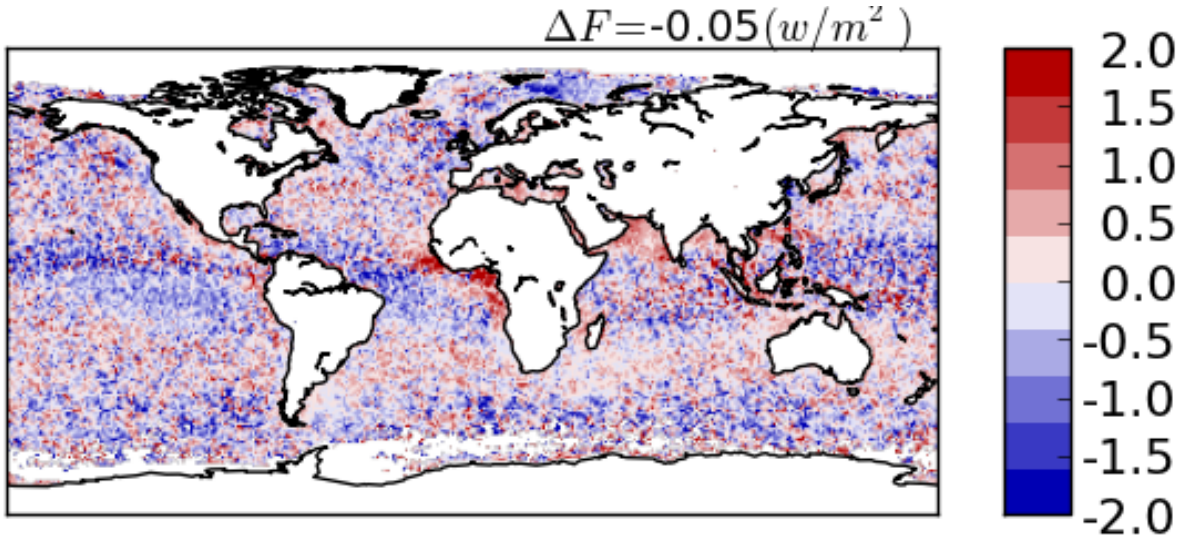
(2004, Aqua rap mode)

ADM performance: Aqua





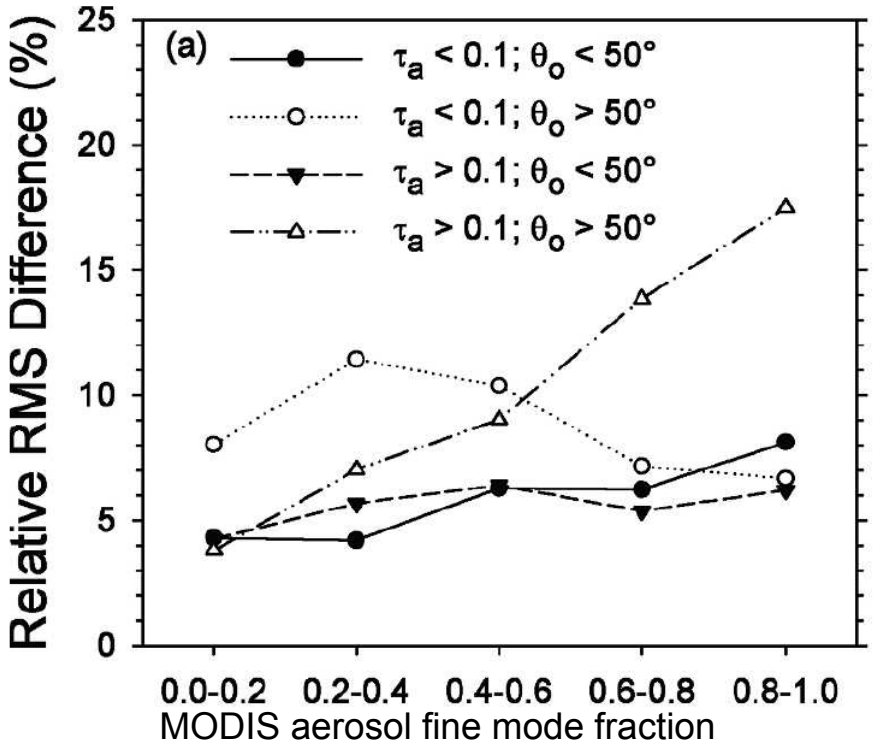




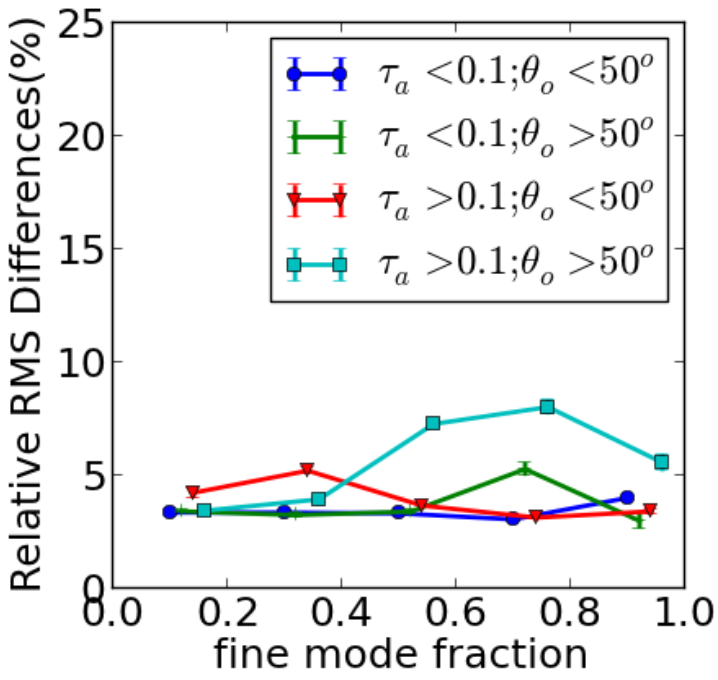
(2004, Aqua rap mode)

Aerosol dependence

Ed2 ADMs



Ed4 ADMs



Summary

- The aerosol dependent clear-sky ADMs over ocean are developed for Ed4. ADMs for both glint > 40° and glint ≤ 40°, respectively.
- For glint > 40°, ADMs are constructed in coarse-mode-like and fine-mode-like aerosols, respectively, and in each of them further in 3 percentile AOD bins; for glint ≤ 40°, ADMs are constructed in 3 percentile AOD bins.
- Compared to the Ed2. ADMs, Ed4. ADMs characterize the clear ocean more accurately. Significant improvements are noticed over coastal regions where heavy dust plumes and pollutions are expected.
- Globally, the ADM RMS reduced from 10.5% to 8.7% for Terra and 11.9% to 10.1% for Aqua. The instantaneous global mean flux is changed by -0.22w/m^2 for Terra and -0.05w/m^2 for Aqua.
- Dependence on aerosol fine mode fraction is reduced in Ed4.ADMs.