Progress in CERES Clear-sky Aerosol Optical Thickness Dependent Shortwave ADM over Ocean

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radiance to flux: clear-sky SW ADM over ocean

1. Sort measured radiances into angular and wind speed bins $(w; \theta_0, \theta, \phi)$ and calculate mean radiances;

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

3. Define anisotropic factor;

4. Convert measured radiances to fluxes;

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

$$\Downarrow$$

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

$$\Downarrow$$

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

$$\Downarrow$$

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

Aerosol in Ed.2 Clear-sky ADM over Ocean

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

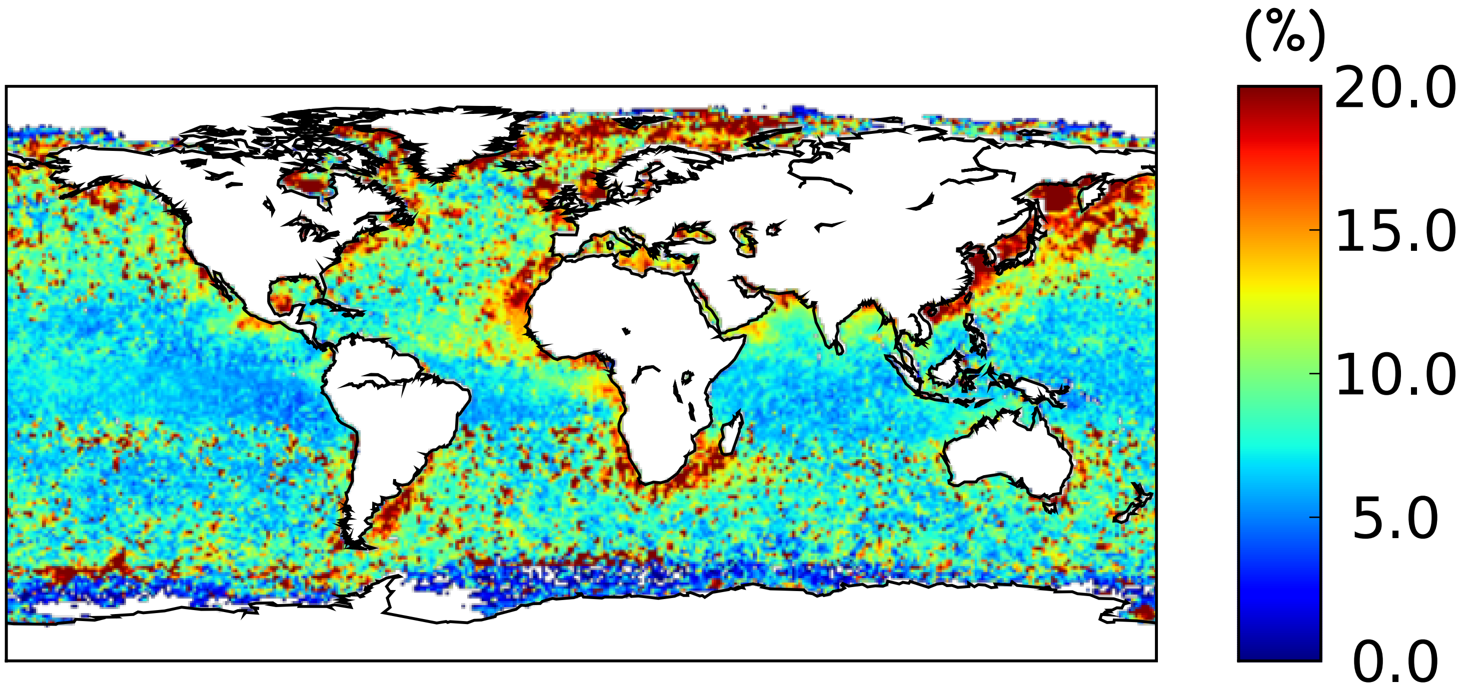
$$F = \frac{\pi I_O}{R\left(\dfrac{R^{th}_{I_O}}{R^{th}_{\hat{I}}}\right)}$$

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

Where to improve?

$$\sqrt{\frac{1}{n}\sum\left(\frac{\hat{I}^i}{\langle\hat{I}\rangle}-\frac{I_O^i}{\langle I_O\rangle}\right)^2} \quad , \ \langle\ \rangle \text{ grid mean}$$

RMS error of normalized radiance differences between ADM-prediction and observation



(Mar 2000 to May 2005, Terra RAP mode)

RMS error is a function of AOD and aerosol type

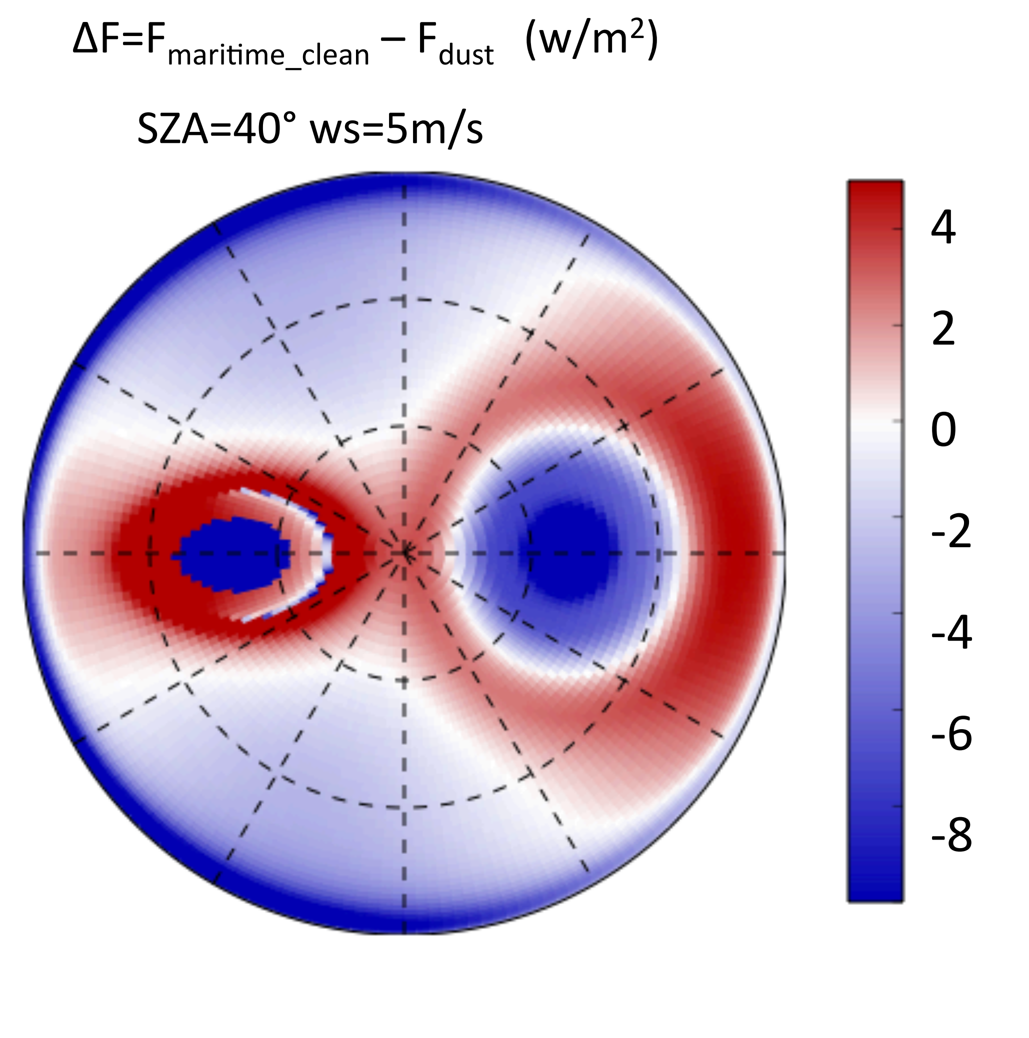
How much error is in flux if the aerosol type is wrong: dust vs. maritime clean aerosol?

1. take a dust aerosol with AOD=0.4, treat F_{dust} as the truth;

2. for radiance value at a viewing angle, retrieve AOD based on maritime clean aerosol model;

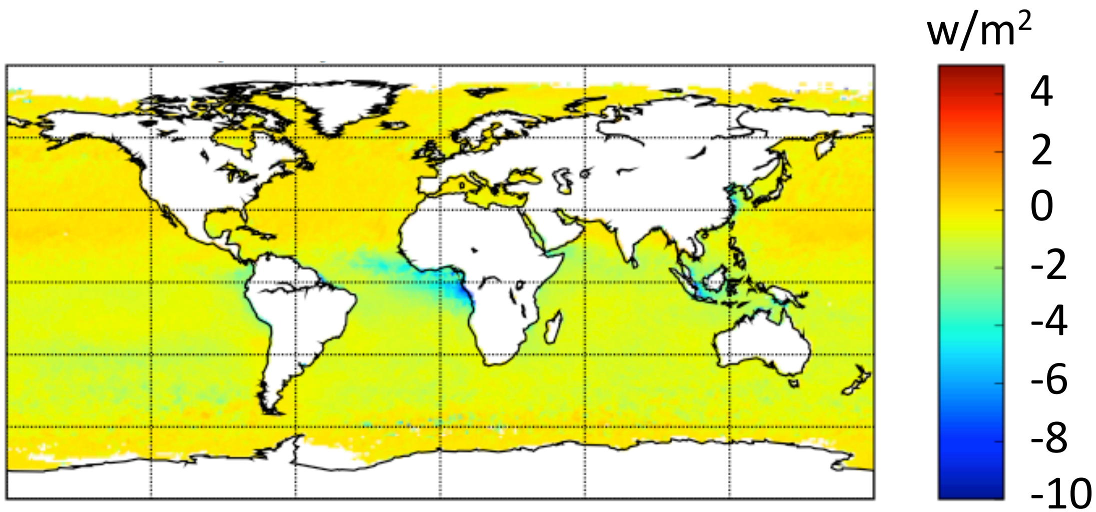
3. convert radiance to flux with theoretical maritime clean aerosol ADM for the retrieved AOD;

4. Get $\Delta F = F_{maritime\_clean} - F_{dust}$ for all viewing angles.

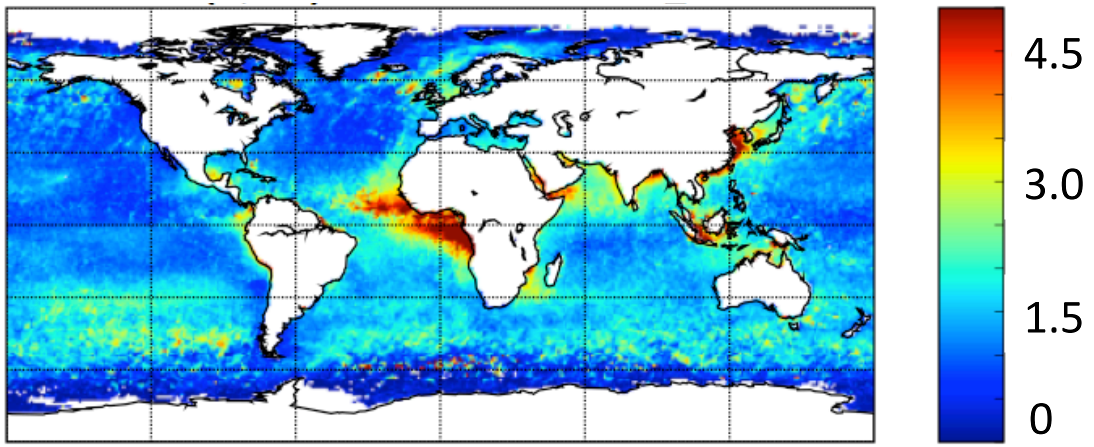


How much error is in flux if the aerosol type is wrong: dust vs. maritime clean aerosol?

$$bias = \frac{1}{n}\sum_{i=1}^{n}\left(F_{1,i} - F_{2,i}\right)$$



$$rmse = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(F_{1,i} - F_{2,i}\right)^2}$$



Aerosol in the new ADM

- As a first step, the AOD-sorted ADM is build; the impact of aerosol type on flux inversion will be evaluated in the future.

- Two options to obtain AOD
  - Use MODIS aerosol product
  - Develop our own version of AOD retrievals

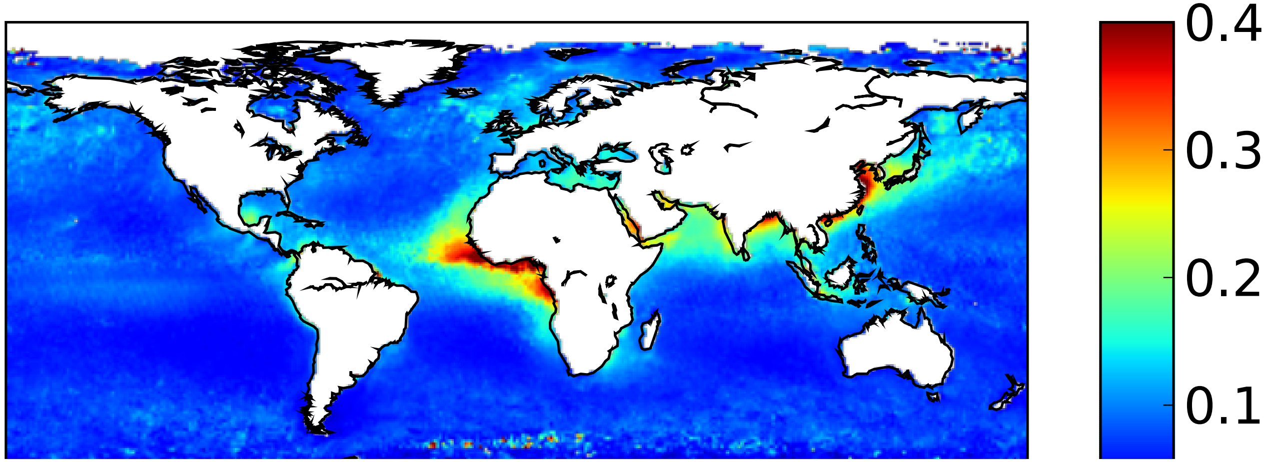
- Why do we prefer to developing our own version of AOD?
  - MODIS AOD is not produced purposely for CERES flux inversion. Not every clear-sky SSF over ocean has a MODIS AOD value, largely because a scene is cloudy-clear by CERES, but not by MODIS.
  - Our own AOD retrieval is self-consistent with CERES cloud mask.

AOD retrieval

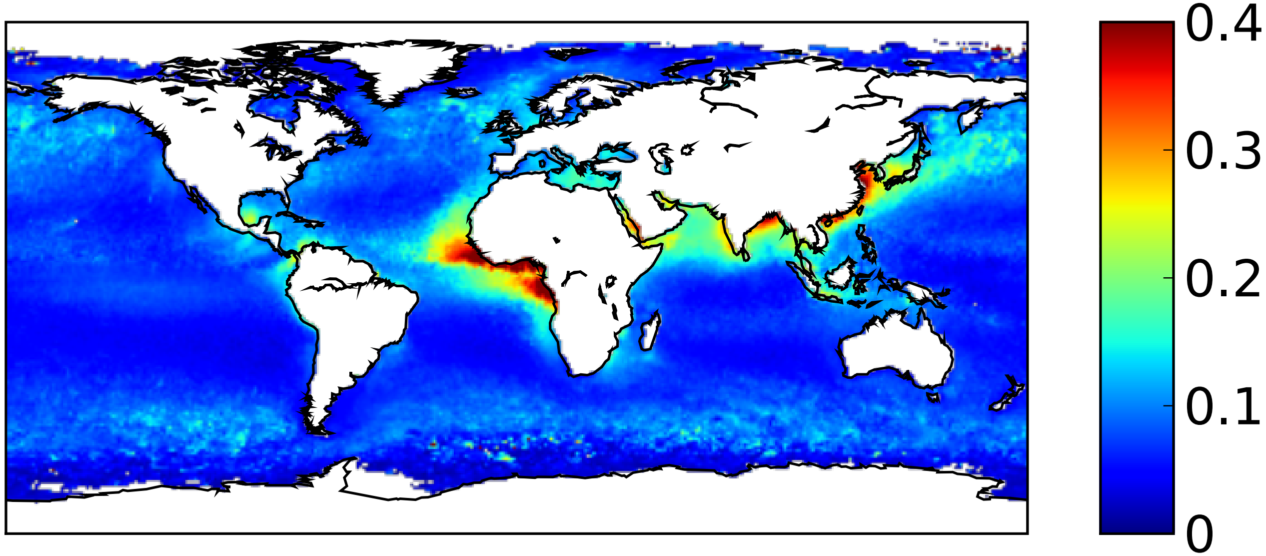
- Only for a clear-sky SSF over ocean with MODIS glint angle > 40°;
- Two MODIS bands (0.64um and 0.86um);
- OPAC maritime tropic aerosol model (Hess et al., 1998);
- DISORT-based radiative transfer model (Kato et al., 2002);
- MODIS spectral RSR function;
- Water vapor absorption based on LBLRTM code;
- Ozone absorption based on 1985 WMO Ozone data;
- Rough ocean surface (taken from 6S RT code).

AOD retrieval - comparison with MODIS

CERES

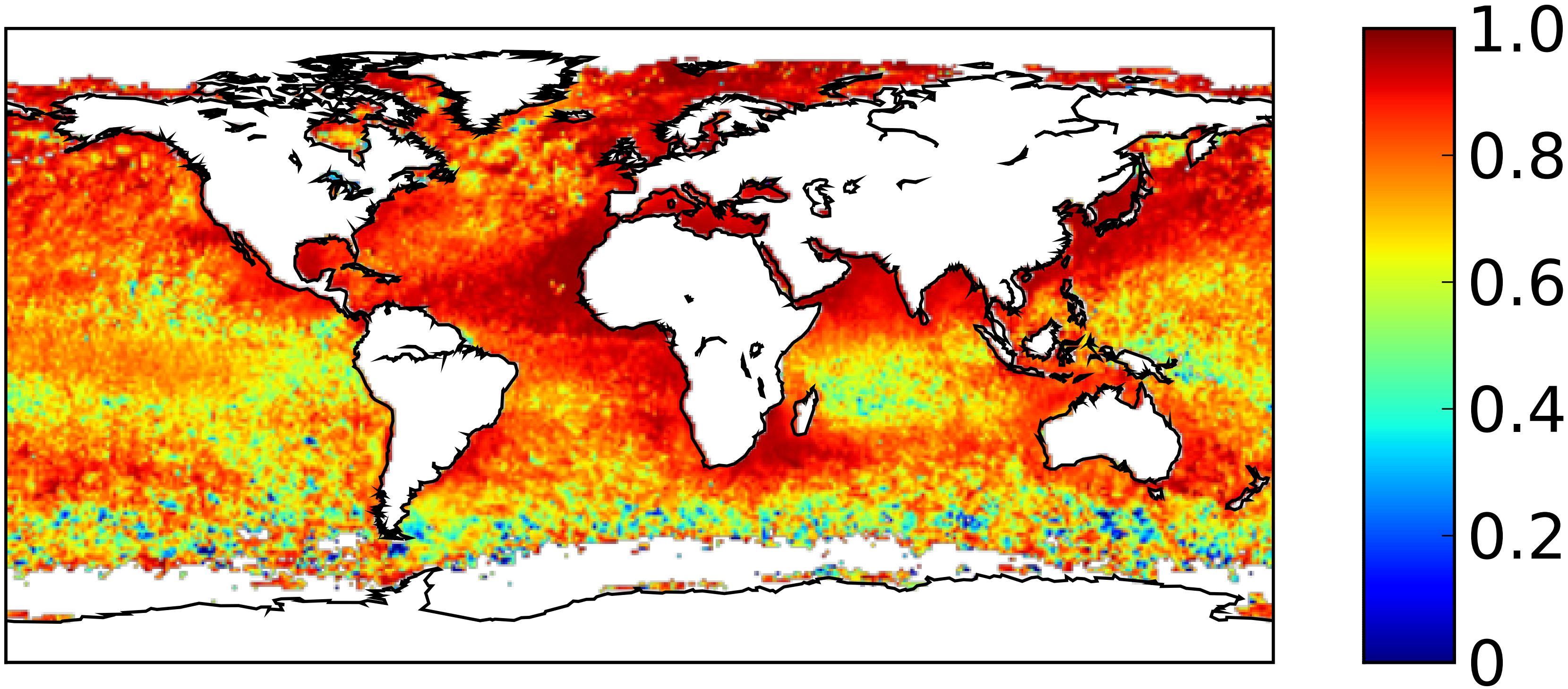


MODIS



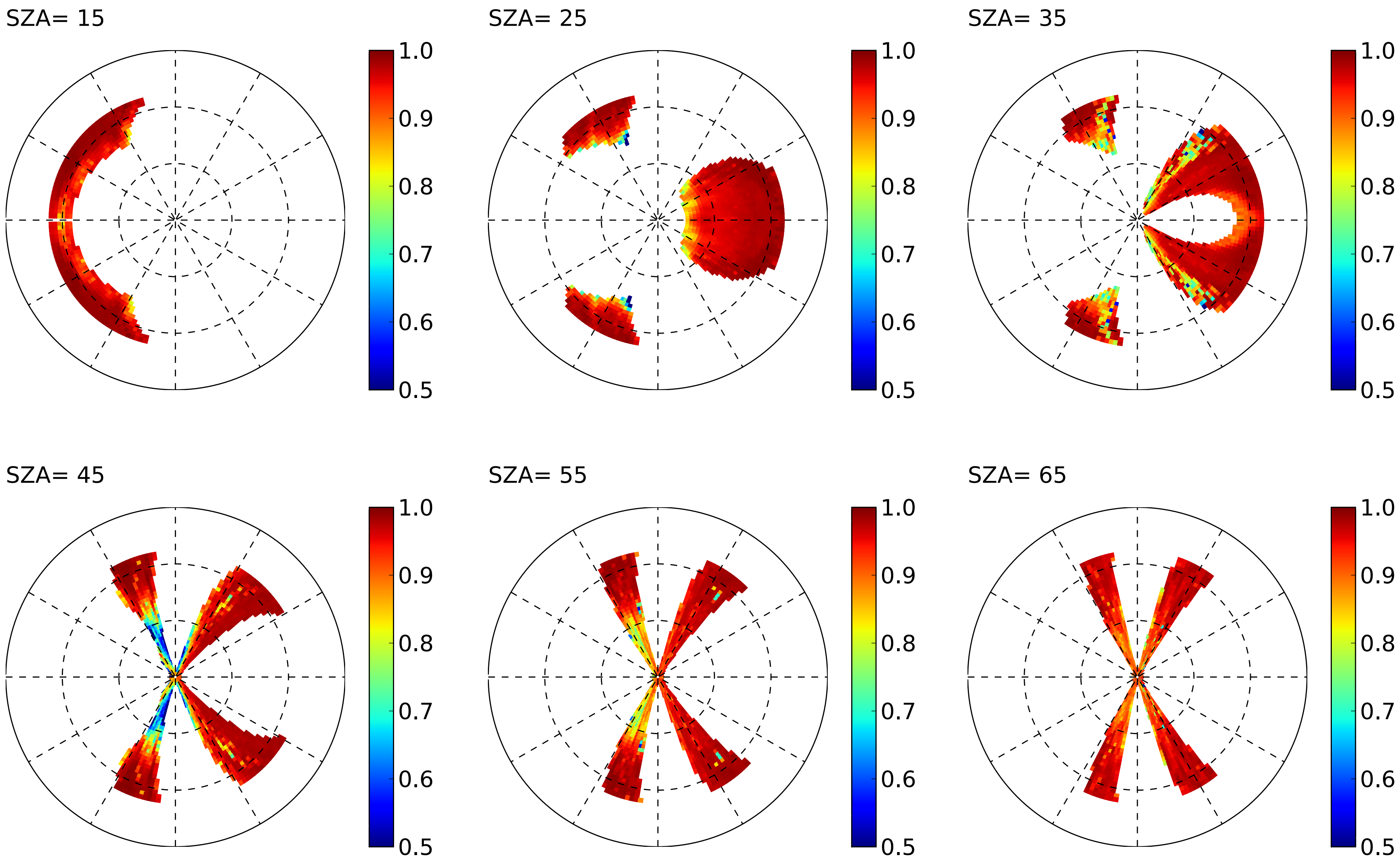
AOD retrieval – correlation with MODIS

correlation coefficient global distribution



AOD retrieval - correlation with MODIS

correlation coefficient in MODIS angular bins



Build low-AOD ADM and high-AOD ADM

1. Bin all AODs into MODIS angular bins (45 SZAs, 45 VZAs and 90 RZAs of MODIS);
2. For the AOD distribution in each angular bin, split the population into 67% scenes with smaller AOD value and 33% scenes with larger AOD value, and thus, define an AOD percentile threshold as well.
3. Construct low-AOD ADM and high-AOD ADM separately.

The percentile approach relaxes the AOD accuracy requirement by mitigating the dependence on solar-view angle, assumptions in aerosol model and retrieval uncertainties.

flux inversion

Is AOD value of a SSF available?
(MODIS sun glint angle > 40°)

YES

infer flux with the low-AOD ADM or high-AOD ADM based on the AOD value against AOD percentile threshold

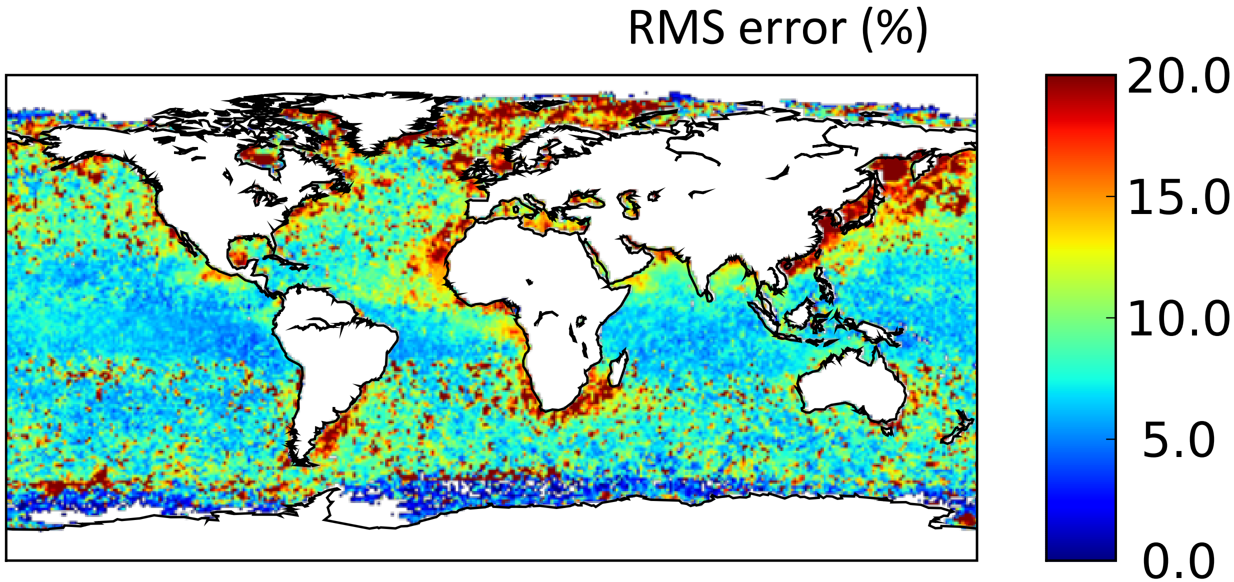
NO

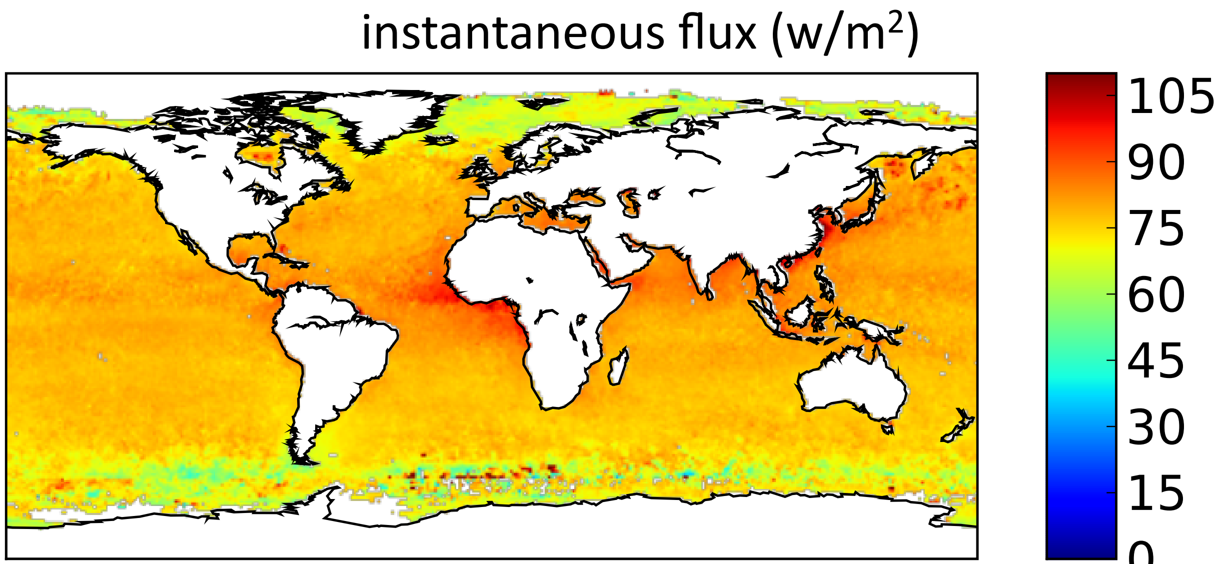
infer flux with the Ed.2 ADM

Ed.2 ADM RMS error and flux

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

$\langle\ \rangle$ grid mean



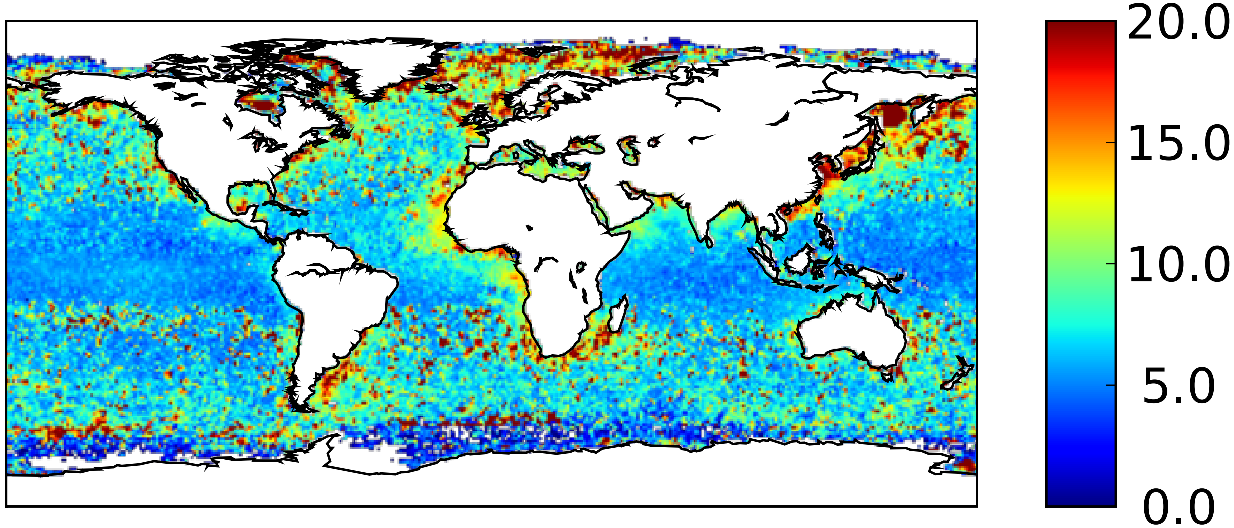


NEW ADM RMS error and flux

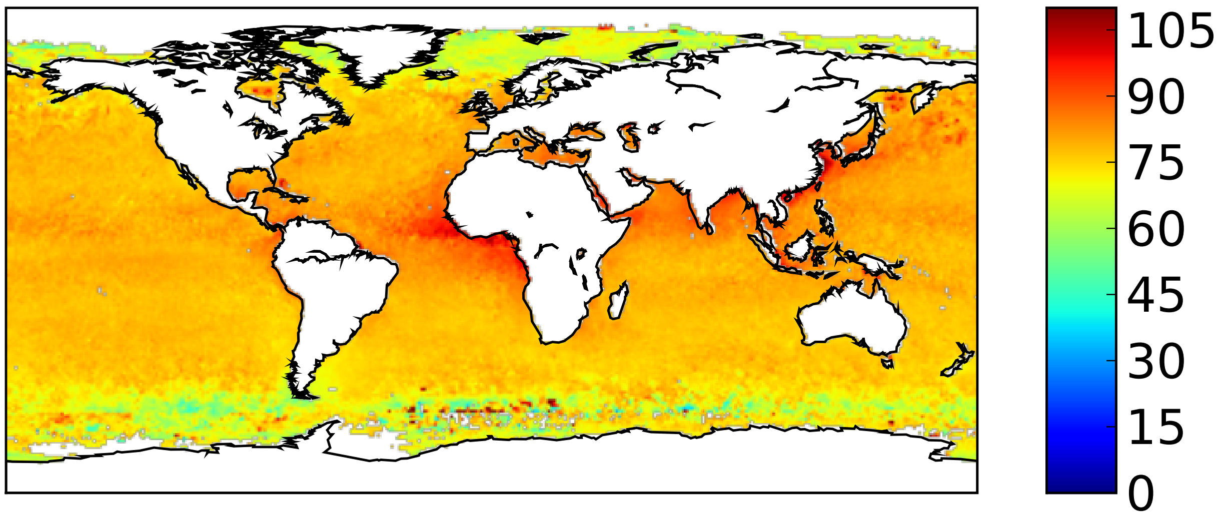
$$\sqrt{\frac{1}{n}\sum\left(\frac{\hat{I}^{i}}{\langle\hat{I}\rangle}-\frac{I_O^{i}}{\langle I_O\rangle}\right)^2}$$

$\langle\ \rangle$ grid mean

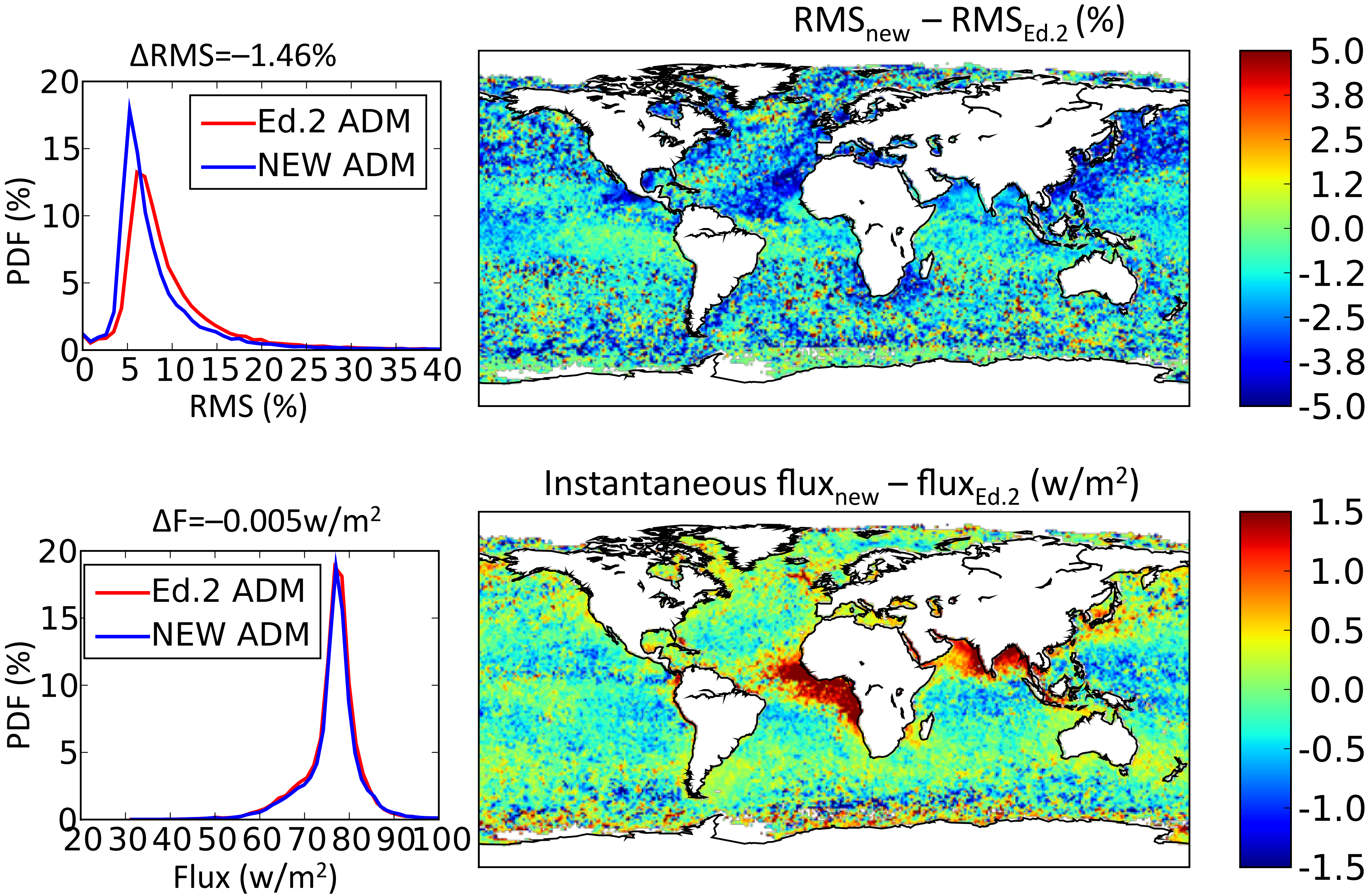
RMS error (%)



instantaneous flux (w/m²)



Differences in RMS error and flux



Summary

- RMS error in the new ADM is reduced globally as compared to Ed.2 ADM; mean reduction over all grids is -1.46%;
- While the mean difference in the instantaneous flux over all grids is nearly unchanged, the geophysical contrast in flux magnitude is enhanced with new ADM, which might be true.

Future work

- Continue to improve aerosol retrieval algorithm: plan to retrieve the fine mode ratio with an algorithm similar to that of MODIS;
- Evaluate the error in aerosol type for flux inversion on the top of AOD-sorted ADM by using the fine mode ratio.